Review

Natural Product Communications
Volume 19(9): 1–30

DOI: 10.1177/1934578X241276962
journals.sagepub.com/home/npx

Glochidion Species: A Review on Phytochemistry and Pharmacology

Nguyen Ngoc Linh[1,#], Nguyen Quang Hop[2,#], Phi Thi Tuyet Nhung[1], Pham Thi Bich Dao[1], Vu Quoc Manh[1], Ty Viet Pham[3] and Ninh The Son[4,5]

Abstract

Objectives: The genus *Glochidion* (the family Phyllanthaceae) is used for various medicinal purposes, such as dysentery, diarrhea, cough, and skin protection. A review of phytochemical and pharmacological aspects for this remains unavailable. The current study tends to sum up a detailed list of phytochemicals, and their role in biological examinations. **Methods:** References in English were obtained by an extensive search across various electronic data sources, encompassing Web of Science, PubMed, Google Scholar, and Science Direct. The "Sci-Finder" was also utilized to find references and revise chemical structures. Referenced documents have been gathered from the 1960s to date. It also noted that *Glochidion*, phytochemistry, and pharmacology are likely the keywords to seek for references. **Results:** Over 240 naturally occurring phytochemicals were isolated and identified from various *Glochidion* tissues, including terpenoids, sterols, saponins, lignans, flavonoids, *mono*-phenols, megastigmanes, butenolides, glycosides, alkaloids, cyanogens, tocopherols, fatty acids, and others. Three naturally occurring triterpenoids glochidonol, glochidiol, and glochidone are the likely characteristic metabolites, being isolated frequently. *Glochidion* crude extracts and their isolated compounds have been demonstrated as potential agents in various pharmacological targets, such as cytotoxicity, antioxidant, anti-inflammation, and neuron and liver protection. **Conclusion:** Several isolates acted as promising agents in pharmacological assays. The anticancer mechanisms of various triterpenoids and saponins, especially new and potential compounds, are expected. Pharmacological advancements to enhance the efficacies of *Glochidion* constituents, such as synergistic combinations and nano-drug formulations, are encouraged.

Keywords

Phyllanthaceae, *Glochidion*, cheese trees, glochidonol, glochidiol, glochidone

Received: May 27th, 2024; Accepted: August 6th, 2024.

Introduction

The genus *Glochidion* contains flowering plants that belong to the family Phyllanthaceae, which was referred to as Cheese trees or Buttonwood in Australia, and Leafflower trees in various scientific documents. About 300 species were recorded, which were widely distributed in the Pacific area, and tropical Asia.[1] Traditionally, *Glochidion* plants have been used for both food and local medicinal purposes, in which they were appropriate for the treatments of various ailments, eg, eczema, rheumatoid, arthritis, influenza, dysentery, impaludism, dyspepsia, cold, and fever.[1–3] The Nicobarese people attested to the therapeutic qualities of *G. calocarpum*, stating that the best treatments for amoebiasis-related, abdominal illnesses are its barks and seeds.[4] *G. multiloculare* fruits were used to cure dysentery, diarrhea, and cough.[5] In Thailand, the shoots and young leaves of *G. hypoleucum* were consumed raw or cooked.[6]

[1]Faculty of Pharmacy, Thanh Do University, 32 Kim Chung, Hoai Duc, Hanoi 10000, Vietnam
[2]Faculty of Chemistry, Hanoi Pedagogical University 2 (HPU2), 32 Nguyen Van Linh, Xuanhoa, Phucyen, Vinhphuc 280000, Vietnam
[3]Faculty of Chemistry, University of Education, Hue University, 34 Le Loi, Hue, 530000, Vietnam
[4]Department of Chemistry, Graduate University of Science and Technology, Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Caugiay, Hanoi 10000, Vietnam
[5]Institute of Chemistry, Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Caugiay, Hanoi 10000, Vietnam

[#]Both authors contributed equally to this work

Corresponding Author:
Ninh The Son (Ph.D), Department of Chemistry, Graduate University of Science and Technology, Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Caugiay, Hanoi 10000, Vietnam.
Email: ntson@ich.vast.vn

Accumulative evidence indicated that species of the genus *Glochidion* were renowned for the presence of diverse phytochemical classes, consisting of the main compounds type terpenoids, sterols, saponins, lignans, flavonoids, *mono*-phenols, and others.[1,7–15] Aliphatic compounds, monoterpenoids, sesquiterpenoids, and their derivatives appeared as the principal compounds in *Glochidion* essential oils.[16,17] Crude extracts and natural compounds of *Glochidion* species have also received much attention in pharmacological studies.[12–17] Triterpenoids and saponins from some Vietnamese *Glochidion* plants with significant cytotoxic results established the potential for anticancer drugs.[11–15] The alcoholic extract of *G. thomsonii* barks showed *in vivo* anti-inflammatory activity against carrageenan-mediated paw edema and xylene-mediated ear edema in mice.[18] Both the aqueous extracts of *G. zylanicum* roots and *G. velutinum* leaves play a great role in *in vivo* antidiabetic activity since they reduce blood glucose levels in mice.[19,20]

To date, there is no in-depth review document on the phytochemical and pharmacological investigations regarding *Glochidion* species. Hence, the ultimate aim of this communication is to highlight the previous results in several aspects, such as natural occurrence, chemical classification, chromatographic isolation, and structural features, especially in terms of pharmacological experimental applications. It is expected that the research will provide a useful scientific foundation for future studies.

Methodology

An extensive survey of the keywords "*Glochidion*'', "Euphorbiaceae", "phytochemistry", and "pharmacology" was conducted in scientific databases, including Pubmed, Scopus, Reaxys, and Google Scholar. The search terms "Bentham Science", "Science Direct", and "Springer", etc were used for data collection. The "Sci-Finder" was also utilized to find references and revise chemical structures. In total, 96 publications were included from the 1960s to March 2024. From these references, 44 publications were used for phytochemistry, and 47 studies for pharmacological activities. Articles focused on morphology were excluded.

Phytochemistry

This is the first time that phytochemical studies of *Glochidion* have been reviewed. A detailed list of *Glochidion* phytochemicals has been alphabetically ordered in Table 1 and Figures 1–6, including terpenoids **1-61**, sterols **62-68**, saponins **69-99**, lignans **100-140**, flavonoids **141-160**, *mono*-phenols **161-183**, megastigmanes **184-199**, butenolides **200-211**, glycosides **212-222**, alkaloids **223-227**, cyanogens **228-232**, tocopherols **233-234**, fatty acids **235-236**, and others **237-239**, as well as compounds isolated from endophytic fungus-associated with *Glochidion* species **240-242**. Herein, the compilation is mostly based on the results of chromatographic columns to completely isolate these compounds as the purified agents, together with the confirmation of their structures by spectroscopic explanations and literature comparisons. In addition, it should be noted that the parts of *G. assamicum*, *G. coccineum*, *G. daltonii*, *G. dasyphyllum*, *G. eriocarpum*, *G. glomerulatum*, *G. heyneanum*, *G. hirsutum*, *G. hohenackeri*, *G. hongkongense*, *G. hypoleucum*, *G. macrophyllum*, *G. moonii*, *G. multiloculare*, *G. obliquum*, *G. obovatum*, *G. philippicum*, *G. puberum*, *G. rubrum*, *G. sphaerogynum*, *G. sumatranum*, *G. velutinum*, *G. venulatum*, *G. wilsonii*, *G. wrightii*, and *G. zeylanicum* are the main source for phytochemical investigations (Table 1).

Terpenoids, Sterols, and Saponins

Terpenoids derived from *Glochidion* plants can be divided into sesquiterpenoids **1-11**,[1,7,8,21] diterpenoid **12**,[10] and triterpenoids **13-61**[9–11,14,22–39] (Table 1 and Figure 1). The most striking feature is that norbisabolane is the principal skeleton of *Glochidion* sesquiterpenoids **1-11**.[1] Xiao et al[8] successfully separated four new derivatives glochinoccins A-D (**1-4**), and two known analogs phyllaemblic acid (**10**) and phyllaemblic acid methyl ester (**11**) from the 90% ethanol extract of *G. coccineum* rhizomes. Two new bisabolane-type sesquiterpenoids glochicoccinosides A-B (**5-6**) were first isolated from *G. hirsutum* aerial parts, and then found in *G. wilsonii* roots.[1,7] Three new sesquiterpenoids glochiwilsonosides A-C (**7-9**) were among the secondary metabolites present in the polar extract of *G. wilsonii* roots.[1] To date, 5-methyl-5-(4,8,12-trimethyltridecyl)-dihydro-furan-2-one (**12**), a secondary metabolite of *G. wrightii* stems and leaves, is a unique diterpenoid detected in the genus *Glochidion*.[10]

As shown in Table 1, triterpenoids can be seen as the main chemical class of *Glochidion*. *G. assamicum*, *G. daltonii*, *G. dasyphyllum*, *G. eriocarpum*, *G. heyneanum*, *G. hohenackeri*, *G. hongkongense*, *G. macrophyllum*, *G. moonii*, *G. multiloculare*, *G. obliquum*, *G. puberum*, *G. sphaerogynum*, *G. venulatum*, *G. wrightii*, and *G. zeylanicum* were the main plants contained triterpenoids. It is also possible to conclude that glochidonol (**32**), glochidiol (**33**), glochidone (**34**), lupeol (**39**), lup-20(29)-ene-1β,3β-diol (**43**), lup-20(29)-ene-3α,23-diol (**45**), and 3-*epi*-lupeol (**49**) were the major components (Table 1). As an example, compound **31** was detectable in *G. daltonii* roots and stems, *G. eriocarpum* aerial parts, roots and stems, *G. heyneanum* aerial parts, *G. hongkongense* stems, *G. macrophyllum* stems, *G. moonii* barks, *G. multiloculare* aerial parts, *G. obliquum* leaves, *G. puberum* stems and twigs, *G. sphaerogynum* roots and stems, *G. venulatum* leaves, *G. wrightii* stems and leaves, and *G. zeylanicum* stem barks.[10,11,23–32,34,36,38,39] Of note, triterpenoid compounds **16-19**, **31-37**, **40-43**, **45**, and **59** were new in the literature.

G. heyneanum aerial parts have been documented to contain two known compounds β-amyrin (**13**) and epimachaerinic acid (**22**), whereas arjunolic acid (**14**) represented *G. assamicum* aerial parts.[30,37] Phytochemical research of the 95% ethanol extract of *G. assamicum* leaves and twigs can lead to the purification of four new triterpenoids 21β-(benzoyloxy) olean-12-ene-3β,16β,23,28-tetraol (**16**), 21β-(benzoyloxy) olean-12-ene-3β,16β,28-triol (**17**), 21β-[(*E*)-cinnamoyloxy]

Table 1. Chemical Constituents from the Genus Glochidion.

No	Compounds	Parts of use	References
Terpenoids			
Sesquiterpenoids			
1	Glochinoccin A	*G. coccineum* rhizomes	[8]
2	Glochinoccin B	*G. coccineum* rhizomes, and *G. wilsonii* roots	[1,8]
3	Glochinoccin C	*G. coccineum* rhizomes	[8]
4	Glochinoccin D	*G. coccineum* rhizomes, *G. puberum* aerial parts, and *G. wilsonii* roots	[1,8,21]
5	Glochicoccinoside A	*G. hirsutum* aerial parts, and *G. wilsonii* roots	[1,7]
6	Glochicoccinoside B	*G. hirsutum* aerial parts, and *G. wilsonii* roots	[1,7]
7	Glochiwilsonoside A	*G. wilsonii* roots	[1]
8	Glochiwilsonoside B	*G. wilsonii* roots	[1]
9	Glochiwilsonoside C	*G. wilsonii* roots	[1]
10	Phyllaemblic acid	*G. coccineum* rhizomes, *G. puberum* aerial parts, and *G. wilsonii* roots	[1,8,21]
11	Phyllaemblic acid methyl ester	*G. coccineum* rhizomes, and *G. wilsonii* roots	[1,8]
Diterpenoid			
12	5-Methyl-5-(4,8,12-trimethyltridecyl)-dihydro-furan-2-one	*G. wrightii* stems and leaves	[10]
Triterpenoids			
13	β-Amyrin	*G. heyneanum* aerial parts	[30]
14	Arjunolic acid	*G. assamicum* aerial parts	[37]
15	Betulin	*G. puberum* stems and twigs, and *G. wrightii* stems and leaves	[10,38]
16	21β-(Benzoyloxy)olean-12-ene-3β,16β,23,28-tetraol	*G. assamicum* leaves and twigs	[9]
17	21β-(Benzoyloxy)olean-12-ene-3β,16β,28-triol	*G. assamicum* leaves and twigs	[9]
18	21β-[(*E*)-Cinnamoyloxy]olean-12-ene-3β,16β,23,28-tetraol	*G. assamicum* leaves and twigs	[9]
19	21β-[(*Z*)-Cinnamoyloxy]olean-12-ene-3β,16β,23,28-tetraol	*G. assamicum* leaves and twigs	[9]
20	*3β-O-trans*-Coumaroylbetulin	*G. puberum* stems and twigs	[38]
21	*3β-O-trans*-Coumaroylbetulinic acid	*G. puberum* stems and twigs	[38]
22	Epimachaerinic acid	*G. heyneanum* aerial parts	[30]
23	5α,6α-Epoxy D:C-friedoolean-8-en-3β-ol	*G. obliquum* leaves	[14]
24	Euphorginol	*G. obliquum* leaves	[35]
25	Friedelin (Friedelan-3-one)	*G. macrophyllum* stems and leaves, *G. obliquum* leaves, *G. puberum* leaves and stems, and *G. wrightii* stems and leaves	[11,23–25,28]
26	Friedelan-3β-ol	*G. macrophyllum* stems and leaves, *G. puberum* leaves and stems, and *G. wrightii* stems and leaves	[10,23–25,28]
27	*3β-O-trans*-Feruloylbetulin	*G. puberum* stems and twigs	[38]
28	*3β-O-trans*-Feruloylbetulinic acid	*G. puberum* stems and twigs	[38]
29	(20*S*)-3α-Hydrolupan-29-oic acid	*G. puberum* stems and twigs	[38]
30	3β-Hydroxyglutin-5-ene (Glutinol)	*G. obliquum* leaves, and *G. wrightii* stems and leaves	[10,11]
31	Glochidol	*G. eriocarpum* stems	[27]
32	Glochidonol	*G. daltonii* roots and stems, *G. eriocarpum* aerial parts, roots and stems, *G. heyneanum* aerial parts, *G. hongkongense* stems, *G. macrophyllum* stems, *G. moonii* barks, *G. multiloculare* aerial parts, *G. obliquum* leaves, *G. puberum* stems and twigs, *G.*	[10,11,23–27,29–32,34,36,38,39]

(Continued)

Table 1. Continued

No	Compounds	Parts of use	References
		sphaerogynum roots and stems, *G. venulatum* leaves, *G. wrightii* stems and leaves, and *G. zeylanicum* stem barks	
33	Glochidiol	*G. assamicum* aerial parts, *G. daltonii* roots and stems, *G. dasyphyllum* stems, *G. eriocarpum* aerial parts, roots and stems, *G. heyneanum* aerial parts, *G. hohenackeri* barks, *G. hongkongense* stems, *G. macrophyllum* stems, *G. moonii* barks, *G. multiloculare* aerial parts, *G. puberum* stems and twigs, *G. sphaerogynum* roots and stems, *G. wrightii* stems and leaves, and *G. zeylanicum* stem barks	22–25,27–32,34,36–39
34	Glochidone	*G. assamicum* aerial parts, *G. daltonii* roots and stems, *G. dasyphyllum* stems, *G. eriocarpum* aerial parts, roots and stems, *G. heyneanum* aerial parts, *G. hohenackeri* barks, *G. hongkongense* stems, *G. macrophyllum* stems, *G. multiloculare* aerial parts, *G. obliquum* leaves, *G. puberum* stems and twigs, *G. wrightii* stems and leaves, and *G. zeylanicum* stem barks	10,11,22–24,27,30–33,36–39
35	Glochidpurnoid A	*G. puberum* stems and twigs	38
36	Glochidpurnoid B	*G. puberum* stems and twigs	38
37	Glochieriol	*G. eriocarpum* aerial parts	34
38	Lupenone	*G. dasyphyllum* stems, *G. eriocarpum* roots and stems, *G. hongkongense* stems, and *G. wrightii* stems	23,24,27,32
39	Lupeol	*G. eriocarpum* aerial parts and stems, *G. hongkongense* stems, *G. multiloculare* aerial parts, *G. obliquum* leaves, *G. puberum* leaves, stems and twigs, and *G. wrightii* stems and leaves	10,11,23,24,27,28,34,36,38
40	Lup-20(29)-ene-1,3-dione	*G. puberum* leaves	28
41	Lup-20(29)-ene-1β-ol-3α-yl acetate	*G. puberum* stems	28
42	Lup-20(29)-ene-3α-ol-1β-yl acetate	*G. puberum* stems	28
43	Lup-20(29)-ene-1β,3β-diol	*G. eriocarpum* aerial parts, roots and stems, *G. heyneanum* aerial parts, *G. macrophyllum* stems, *G. wrightii* stems and leaves, and *G. zeylanicum* stem barks	10,24,27,30–33
44	Lup-20(29)-ene-3β,16β-diol	*G. wrightii* stems and leaves	10
45	Lup-20(29)-ene-3α,23-diol	*G. daltonii* roots and stems, *G. macrophyllum* stems, *G. moonii* barks, *G. sphaerogynum* roots and stems, and *G. puberum* stems and twigs	25,29,32,38,39

(Continued)

Table 1. Continued

No	Compounds	Parts of use	References
46	Lup-20(29)-ene-3β,23-diol	*G. eriocarpum* aerial parts	[33]
47	Lup-20(30)-ene-3β,29-diol	*G. puberum* stems and twigs	[38]
48	3α,20-Lupandiol	*G. puberum* stems and twigs	[38]
49	3-*epi*-Lupeol	*G. daltonii* roots and stems, *G. eriocarpum* aerial parts, roots and stems, *G. hohenackeri* barks, *G. hongkongense* stems, and *G. puberum* stems and twigs	[22,24,32,34,38,39]
50	29-*nor*-Lup-1-ene-3,20-dione	*G. puberum* stems and twigs	[38]
51	Maslinic acid	*G. wrightii* stems and leaves	[10]
52	Morolic acid acetate	*G. puberum* stems and twigs	[38]
53	Obibanmol I	*G. puberum* stems and twigs	[38]
54	Oleanolic acid	*G. wrightii* stems and leaves	[10]
55	Rotundic acid	*G. obliquum* leaves	[35]
56	Simiarenol	*G. wrightii* stems and leaves	[10]
57	3,4-Secofriedelan-3-oic acid	*G. wrightii* stems and leaves	[10]
58	Taraxerol	*G. obliquum* leaves	[35]
59	3β-Tetradecanoyloxy-1β-hydroxylup-20(29)-ene	*G. wrightii* stems and leaves	[10]
60	2,3,24-Trihydroxyurs-12-en-28-oic acid	*G. obliquum* leaves	[35]
61	Ursolic acid	*G. wrightii* stems and leaves	[10]
Sterols			
62	Chlorogenin	*G. assamicum* aerial parts	[37]
63	β-Sitosterol	*G. dasyphyllum* stems and leaves, *G. eriocarpum* stems, *G. hongkongense* stems and leaves, *G. macrophyllum* stems and leaves, *G. moonii* barks, *G. obliquum* leaves, *G. puberum* aerial parts, leaves and stems, *G. venulatum* leaves, and *G. wrightii* stems and leaves	[10,23–29,35,40]
64	Sistosterol-5-en-3β-hydroxy-7-one	*G. wrightii* stems and leaves	[10]
65	Sistosterol-5-en-3β,7α-diol	*G. wrightii* stems and leaves	[10]
66	Sistosterol-5-en-3β,7β-diol	*G. wrightii* stems and leaves	[10]
67	Stigmasterol	*G. dasyphyllum* stems, *G. heyneanum* aerial parts, *G. macrophyllum* stems and leaves, and *G. multiloculare* aerial parts	[24,25,30,36]
68	Stigmast-6β-hydroxyl-4-en-3-one	*G. wrightii* stems and leaves	[10]
Saponins			
69	Assamicoside A	*G. assamicum* aerial parts	[37]
70	Daucosterol	*G. heyneanum* aerial parts, *G. multiloculare* aerial parts, *G. obliquum* leaves, *G. puberum* aerial parts, and *G. wrightii* stems and leaves	[10,30,35,36,40]
71	Glochidioside	*G. coccineum* rhizomes, and *G. heyneanum* aerial parts	[21,41]
72	Glochidioside N	*G. heyneanum* aerial parts	[30]
73	Glochidioside Q	*G. heyneanum* aerial parts	[30]
74	Glochierioside A	*G. eriocarpum* aerial parts	[33]
75	Glochierioside B	*G. eriocarpum* aerial parts	[33]
76	Glochierioside C	*G. eriocarpum* aerial parts	[34]
77	Glochierioside D	*G. eriocarpum* aerial parts	[34]
78	Glochierioside E	*G. eriocarpum* aerial parts	[34]
79	Glomeruloside A	*G. glomerulatum* leaves	[11]
80	Glomeruloside B	*G. glomerulatum* leaves	[11]
81	Glomeruloside C	*G. glomerulatum* leaves	[11]

(Continued)

Table 1. Continued

No	Compounds	Parts of use	References
82	Glomeruloside D	*G. glomerulatum* leaves	11
83	Glomeruloside E	*G. glomerulatum* leaves	11
84	Glomeruloside F	*G. glomerulatum* leaves	11
85	Glomeruloside G	*G. glomerulatum* leaves	11
86	Glomeruloside H	*G. glomerulatum* leaves	11
87	Glomeruloside I	*G. glomerulatum* leaves	13
88	Glomeruloside II	*G. glomerulatum* leaves	13
89	Hirsutoside A	*G. hirsutum* leaves	42
90	Hirsutoside B	*G. hirsutum* leaves	42
91	Hirsutoside C	*G. hirsutum* leaves	42
92	Hirsutoside D	*G. hirsutum* leaves	42
93	Hirsutoside E	*G. hirsutum* leaves	42
94	Puberoside A	*G. puberum* aerial parts	43
95	Puberoside B	*G. puberum* aerial parts	43
96	Puberoside C	*G. puberum* aerial parts	44
97	Puberoside D	*G. puberum* aerial parts	44
98	Puberoside E	*G. puberum* aerial parts	44
99	Pedunculoside	*G. obliquum* leaves	35
Lignans			
Aryltetralins			
100	(+)-Isolariciresinol	*G. wilsonii* roots	1
101	(+)-Isolariciresinol 2a-*O*-*β*-D-glucopyranoside ((+)-Isolariciresinol 9-*O*-*β*-D-glucopyranoside)	*G. rubrum* leaves, *G. wilsonii* roots, and *G. zeylanicum* leaves	1,45,46
102	(–)-Isolariciresinol 2a-*O*-*β*-D-glucopyranoside	*G. rubrum* leaves	46
103	(+)-Isolariciresinol 3a-*O*-*β*-D-glucopyranoside	*G. rubrum* leaves, and *G. zeylanicum* leaves	45,46
104	(+)-Isolariciresinol 9-*O*-*β*-D-xylopyranoside	*G. wilsonii* roots	1
105	(+)-Isolariciresinol 9'-*O*-*β*-D-xylopyranoside	*G. wilsonii* roots	1
106	(–)-Secoisol ariciresinol	*G. wilsonii* roots	1
Furan			
107	(+)-Laricerisnol	*G. wilsonii* roots, and *G. wrightii* stems and leaves	1,10
Furofurans			
108	Balanophonin B	*G. wilsonii* roots	1
109	Clemaphenol A	*G. wilsonii* roots	1
110	4,4'-Dimethoxy-3'-hydroxy-7,9':7′,9-diepoxylignan-3-*O*-*β*-*D*-glucopyranoside	*G. coccineum* rhizomes	47
111	(+)-Mediresinol	*G. assamicum* aerial parts, and *G. wilsonii* roots	1,37
112	(+)-Pinoresinol	*G. obliquum* leaves, *G. wrightii* stems and leaves, and *G. wilsonii* roots	1,10,15
113	(+)-Syringaresinol	*G. obliquum* leaves, *G. puberum* aerial parts, *G. wilsonii* roots, and *G. wrightii* stems and leaves	1,10,15,40
114	Yangambin	*G. wilsonii* roots	1
Phenylpropanoids			
115	Dihydroconiferyl alcohol	*G. wilsonii* roots	1
116	(*E*)-4-Hydroxycinnamyl alcohol-4-*O*-*β*-D-glucopyranoside	*G. wilsonii* roots	1
117	Evofolin B	*G. wilsonii* roots	1
118	*rel*-(1*R*,2*S*)-1,2-*bis* (4-Hydroxy-3-methoxy-phenyl)-1,3-propanediol	*G. wilsonii* roots	1
119	Leptolepisol C	*G. wilsonii* roots	1
120	Leptolepisol D	*G. wilsonii* roots	1
121	Syringin	*G. eriocarpum* whole plant, and *G. obliquum* leaves	35,48
122	(7*R*,8*S*)-4,7,9,9'-Tetrahydroxy-3,3'-dimethoxy-8-*O*-4'-neolignan 7-*O*-*β*-D-glucopyranoside	*G. rubrum* leaves	46
123		*G. rubrum* leaves	46

(Continued)

Table 1. Continued

No	Compounds	Parts of use	References
	(7*R*,8*R*)-4,7,9,9'-Tetrahydroxy-3,3'-dimethoxy-8-*O*-4'-neolignan 7-*O*-*β*-D-glucopyranoside		
Benzofurans			
124	9'-Dehydro-valadion F	*G. wilsonii* roots	1
125	Dehydrodiconiferyl alcohol	*G. wilsonii* roots	1
126	Dihydrodehydrodiconiferyl alcohol	*G. wilsonii* roots	1
127	Dihydrodehydrodiconiferyl alcohol 9'-*O*-sulfate	*G. zeylanicum* leaves	45
128	7*R*,8*S*-Dihydrodehydrodiconiferyl alcohol 4-*O*-*β*-D-glucopyranoside	*G. eriocarpum* whole plant, and *G. zeylanicum* leaves	45,48
129	7*S*,8*R*-Dihydrodehydrodiconiferyl alcohol 4-*O*-*β*-D-glucopyranoside	*G. eriocarpum* whole plant, and *G. zeylanicum* leaves	45,48
130	Dihydrodehydrodiconiferyl alcohol 9-*O*-*β*-D-glucopyranoside	*G. zeylanicum* leaves	45
131	9,9'-Dihydroxy-3,4-methylenedioxy-3'-methoxy [7-*O*-4',8-5'] neolignan	*G. wilsonii* roots	1
132	Glochidioboside (Dihydrodehydrodiconiferyl alcohol 9'-*O*-*β*-D-glucopyranoside)	*G. obliquum* leaves, and *G. zeylanicum* leaves	45,49
133	Glochiwilsonise A	*G. wilsonii* roots	1
134	Glochiwilsonise B	*G. wilsonii* roots	1
135	Glochiwilsonise C	*G. wilsonii* roots	1
136	Glochiwilsonise D	*G. wilsonii* roots	1
137	Glochiwilsonise E	*G. wilsonii* roots	1
138	4-*O*-Methylcedrusin	*G. wilsonii* roots	1
139	Phyllnirurin	*G. wilsonii* roots	1
Lignanoid			
140	Glochinin A	*G. puberum* aerial parts	21
Flavonoids			
Flavones			
141	6''-*O*-Acetylorientin	*G. obliquum* leaves	15
142	Globlin A	*G. obliquum* leaves	35
143	Isoorientin	*G. hypoleucum* leaves, and *G. zeylanicum* leaves	6,50
144	Isovitexin	*G. hirsutum* stems	7
145	Isovitexin 7-*O*-xyloside	*G. hirsutum* stems	7
146	Orientin	*G. hypoleucum* leaves	6
147	Vitexin	*G. hypoleucum* leaves, *G. obliquum* leaves, *G. puberum* aerial parts, and *G. zeylanicum* leaves	6,15,35,40,50
Flavans			
148	(+)-Epigallocatechin 3-*O*-gallate	*G. acuminatum* leaves	51
149	Glochiflavanoside A	*G. zeylanicum* leaves	50
150	Glochiflavanoside B	*G. zeylanicum* leaves	50
151	Glochiflavanoside C	*G. zeylanicum* leaves	50
152	Glochiflavanoside D	*G. zeylanicum* leaves	50
153	Glochiin C_1	*G. rubrum* leaves	52
Flavanones			
154	(2*R*,3*R*)-Dihydromyricetin-4'-*O*-(3''-*O*-methyl)-gallate	*G. sumatranum* leaves and twigs	53
155	(2*R*,3*R*)-Dihydromyricetin-3'-*O*-(3''-*O*-methyl)-gallate	*G. sumatranum* leaves and twigs	53
156	(2*R*,3*R*)-Dihydromyricetin-4'-*O*-gallate	*G. sumatranum* leaves and twigs	53
157	(2*R*,3*R*)-Dihydromyricetin-3'-*O*-gallate	*G. sumatranum* leaves and twigs	53
158	(2*R*,3*R*)-Dihydromyricetin	*G. sumatranum* leaves and twigs	53
159	Naringenin	*G. wrightii* stems and leaves	10
Chalcone			
160	Phloretin 4'-*O*-*β*-D-glucopyranoside	*G. acuminatum* leaves	51
***Mono*-phenols**			
161	Bergenin	*G. eriocarpum* whole plant, *G. hirsutum* stems, *G. obliquum* leaves, *G. obovatum* leaves, *G.*	1,7,35,46,48,49

(Continued)

Table 1. Continued

No	Compounds	Parts of use	References
		rubrum leaves, and *G. wilsonii* roots	
162	Decoumaroylibotanolide	*G. hirsutum* stems	7
163	4-*O*-Ethylgallic acid	*G. assamicum* aerial parts, *G. hirsutum* stems, and *G. puberum* aerial parts	7,37,40
164	1,2-Dimethoxyphenyl-4-*O*-*β*-D-glucoside	*G. eriocarpum* whole plant	48
165	3,4-Dimethoxyphenyl-*β*-D-glucoside	*G. assamicum* aerial parts	37
166	Gallic acid	*G. hypoleucum* leaves, and *G. puberum* aerial parts	6,40
167	1-*β*-D-Glucopyranosyloxy-3-methoxy-5-hydroxybenzene	*G. eriocarpum* whole plant	48
168	Glochidacuminoside A	*G. acuminatum* leaves, and *G. wilsonii* roots	1,54
169	Glochiin M_1	*G. rubrum* leaves	52
170	Glochiin M_2	*G. rubrum* leaves	52
171	Glochiwilsophenoside	*G. wilsonii* roots	1
172	2-*β*-D-Glucopyranosyloxy-4-methoxy-6-hydroxy-isovalero-phenone	*G. eriocarpum* whole plant	48
173	Glucosyringic acid	*G. wilsonii* roots	1
174	*p*-Hydroxybenzaldehyde	*G. wilsonii* roots	1
175	Koaburaside	*G. eriocarpum* whole plant	48
176	Koaburaside monomethyl ether	*G. eriocarpum* whole plant	48
177	Methyl gallate	*G. hypoleucum* leaves, and *G. superbum* leaves	6,55
178	Methyl 2-(2-hydroxyphenyl) acetate *β*-D-glucopyranoside	*G. acuminatum* leaves	51
179	3-*O*-Methylgallic acid	*G. hirsutum* stems	7
180	Syringaldehyde	*G. wilsonii* roots	1
181	Tachioside 2'-*O*-4''-*O*-methylgallate	*G. rubrum* leaves	46
182	24,6-Trimethoxyphenol-1-*O*-*β*-D-glucoside	*G. assamicum* aerial parts, and *G. wilsonii* roots	1,37
183	Vanillic acid-4-*O*-*β*-D-glucopyranoside	*G. wilsonii* roots	1
Megastigmanes			
184	Blumenol C glucoside	*G. eriocarpum* whole plant, *G. obliquum* leaves, and *G. zeylanicum* leaves	48,49,56
185	Cannabiside D	*G. eriocarpum* whole plant	48
186	Corchoionoside C	*G. assamicum* aerial parts, and *G. rubrum* leaves	37,46
187	Dendranthemoside B	*G. obliquum* leaves	49
188	6*β*,9*β*:9,13-Diepoxymegastig-4-en-3*β*-ol	*G. obliquum* leaves	14
189	Glochidionionoside A	*G. eriocarpum* whole plant, *G. rubrum* leaves, and *G. zeylanicum* leaves	46,48,56
190	Glochidionionoside B	*G. rubrum* leaves, and *G. zeylanicum* leaves	46,56
191	Glochidionionoside C	*G. eriocarpum* whole plant, *G. rubrum* leaves, and *G. zeylanicum* leaves	46,48,56
192	Glcochidionionoside D	*G. zeylanicum* leaves	56
193	Glochidionionoside E	*G. eriocarpum* whole plant, and *G. zeylanicum* leaves	48,56
194	(*Z*)-4-[3'-(*β*-D-Glucopyranosyloxy) butylidene]-35,5-trimethyl-2-cyclohexen-l-one	*G. eriocarpum* whole plant	48
195	Icariside B_1	*G. obliquum* leaves	49
196	(6*R*,9*S*)-3-*oxo*-*α*-Ionol *β*-D-glucopyranoside	*G. eriocarpum* whole plant	48
197	(3*S*,5*R*,6*R*,7*E*,9*S*)-Megastigman-7-ene-3,5,6,9-tetrol 3-*O*-*β*-D-glucopyranoside	*G. zeylanicum* leaves	57
198	(3*S*,5*R*,6*R*,7*E*,9*S*)-Megastigman-7-ene-3,5,6,9-tetrol 9-*O*-*β*-D-glucopyranoside	*G. zeylanicum* leaves	57

(Continued)

Table 1. Continued

No	Compounds	Parts of use	References
199	(6*S*,9*S*)-Roseoside	*G. eriocarpum* whole plant	48
Butenolides			
200	(+)-Aquilegiolide	*G. acuminatum* leaves	51
201	Isoglochidiolide	*G. acuminatum* leaves	54
202	Glochidiolide	*G. acuminatum* leaves, and *G. wilsonii* roots	1,54,58
203	Glochidionolactone A	*G. zeylanicum* leaves	59
204	Glochidionolactone B	*G. zeylanicum* leaves	59
205	Glochidionolactone C	*G. zeylanicum* leaves	59
206	Glochidionolactone D	*G. zeylanicum* leaves	59
207	Glochidionolactone E	*G. zeylanicum* leaves	59
208	Glochidionolactone F	*G. zeylanicum* leaves	59
209	(–)-Loliolide	*G. acuminatum* leaves	51
210	(+)-Menisdaurilide	*G. acuminatum* leaves	51
211	Phyllanthurinolactone	*G. zeylanicum* leaves	59
Glycosides			
212	Icariside D_1	*G. rubrum* leaves	46
213	Icariside F_2	*G. assamicum* aerial parts, and *G. rubrum* leaves	37,46
214	*β*-D-Galactopyranosyl-(3→3)-*O*-*β*-D-galactopyranose	*G. puberum* aerial parts	40
215	*n*-Butyl-*α*-D-fructofuranoside	*G. hirsutum* stems	7
216	*n*-Butyl-*β*-D-fructofuranoside	*G. hirsutum* stems	7
217	*E*-2-Hexenyl-D-glucopyranoside	*G. puberum* aerial parts	40
218	Glochidacuminoside B	*G. acuminatum* leaves	54
219	Glochidacuminoside C	*G. acuminatum* leaves	54
220	*Z*-3-Hexenyl-D-glucopyranoside	*G. acuminatum* leaves, and *G. puberum* aerial parts	40,54
221	D-Mannitol	*G. heyneanum* aerial parts	30
222	*myo*-Inositol	*G. obliquum* leaves	35
Alkaloids			
223	Acumiaminoside	*G. acuminatum* leaves	54
224	Glochidine	*G. philippicum* leaves	60
225	Glochidicine	*G. philippicum* leaves	60
226	N^{α}-(4-Oxodecanoyl)-histamine	*G. philippicum* leaves	60
227	N^{α}-cinnamoylhistamine	*G. philippicum* leaves	60
Cyanogens			
228	2-(2,4-Dihydroxyphenyl) acetonitrile 2-*O*-*β*-D-glucopyranoside 6'-*O*-p-hydroxybenzoate	*G. acuminatum* leaves	51
229	2-(2,4-Dihydroxyphenyl) acetonitrile 2-*O*-*β*-D-glucopyranoside 6'-*O*-(S)-2-(4-hydrocyclohex-1-en-1-yl)acetate	*G. acuminatum* leaves	51
230	2-(2,4-Dihydroxyphenyl) acetonitrile 2-*O*-*β*-D-glucopyranoside 6'-*O*-gallate	*G. acuminatum* leaves	51
231	2-(2,4-Dihydroxyphenyl) acetonitrile 2-*O*-*β*-D-glucopyranoside 3',6'-*O*-digallate	*G. acuminatum* leaves	51
232	Glochidacuminoside D	*G. acuminatum* leaves	54
Tocopherols			
233	*α*-Tocospiro A	*G. wrightii* stems and leaves	10
234	*β*-Tocospiro B	*G. wrightii* stems and leaves	10
Fatty acids			
235	(9*E*,11*E*)-13-*oxo*-9, 11-Octadecadienoic acid	*G. wilsonii* roots	1
236	Rabdosia acid A	*G. wilsonii* roots	1
Others			
237	(*S*)-Methyl 2-[4-sulfooxycyclohex-1-en-1-yl] acetate	*G. acuminatum* leaves	51
238	*p*-Pentadecayl ethyl cinnamate	*G. velutinum* leaves	61
239	Resveratrol-12-C-*β*-glucopyranoside	*G. wilsonii* roots	1
Compounds isolated from endophytic fungus-associated with *Glochidion* species			
240	Eupenoxide		62

(Continued)

Table 1. Continued

No	Compounds	Parts of use	References
		Eupenicillium sp.-parasited *G. ferdinandi*	
241	Phomoxin B	*Eupenicillium* sp.-parasited *G. ferdinandi*	[62]
242	Phomoxin C	*Eupenicillium* sp.-parasited *G. ferdinandi*	[62]

olean-12-ene-3β,16β,23,28-tetraol (**18**), and 21β-[(*Z*)-cinnamoyloxy]olean-12-ene-3β,16β,23,28-tetraol (**19**).[9] A report in 2023 indicated that the 95% ethanol extract of *G. puberum* stems and twigs encompassed two new metabolites glochidpurnoids A-B (**35-36**), and the known ones betulin (**15**), 3β-*O*-*trans*-coumaroylbetulin (**20**), 3β-*O*-*trans*-coumaroylbetulinic acid (**21**), 3β-*O*-*trans*-feruloylbetulin (**27**), 3β-*O*-*trans*-feruloylbetulinic acid (**28**), (20*S*)-3α-hydrolupan-29-oic acid (**29**), glochidonol (**32**), glochidiol (**33**), glochidone (**34**), lupeol (**39**), lup-20(29)-ene-3α,23-diol (**45**), lup-20(30)-ene-3β,29-diol (**47**), 3α,20-lupandiol (**48**), 3-*epi*-lupeol (**49**), morolic acid acetate (**52**), and obibanmol I (**53**).[38]

Besides the known triterpenoids, two new analogs 5α,6α-epoxy D:C-friedoolean-8-en-3β-ol (**23**) and glochieriol (**37**) have been observed in Vietnamese *G. obliquum* leaves and *G. eriocarpum* aerial parts, respectively.[14,34] In the meantime, glochidol (**31**) was also a new triterpenoid found in Chinese *G. eriocarpum* stems.[27] New triterpenoid lup-20(29)-ene-1,3-dione (**40**) originated from *G. puberum* leaves, while its stems consisted two new ones lup-20(29)-ene-1β-ol-3α-yl acetate (**41**), and lup-20(29)-ene-3α-ol-1β-yl acetate (**43**).[28] Two new triterpenoids lup-20(29)-ene-1β,3β-diol (**43**) and lup-20(29)-ene-3α,23-diol (**45**) were first isolated from *G. macrophyllum* stems.[24,25] They were then found to be available in the genus *Glochidion* (Table 1). Among various triterpenoids in the 95% ethanol extract of *G. wrightii* stems and leaves, 3β-tetradecanoyloxy-1β-hydroxylup-20(29)-ene (**59**) was elucidated as a new triterpenoid.[10]

The known compounds **62-68** belong to the group of sterols (Table 1 and Figure 1).[10,23–29,35,40] β-Sitosterol (**63**) was isolated frequently, which it was detected in *G. dasyphyllum* stems and leaves, *G. eriocarpum* stems, *G. hongkongense* stems and leaves, *G. macrophyllum* stems and leaves, *G. moonii* barks, *G. obliquum* leaves, *G. puberum* aerial parts, leaves and stems, *G. venulatum* leaves, and *G. wrightii* stems and leaves.[10,23–29,35,40] Similarly, stigmasterol (**67**) was also a characteristic sterol present in this genus, and it can be found in *G. dasyphyllum* stems, *G. heyneanum* aerial parts, *G. macrophyllum* stems and leaves, and *G. multiloculare* aerial parts.[24,25,30,36] *G. assamicum* aerial parts was reported to contain chlorogenin (**62**), while the 95% methanol extract of *G. wrightii* stems and leaves was associated with the appearance of sistosterol-5-en-3β-hydroxy-7-one (**64**), sistosterol-5-en-3β,7α-diol (**65**), sitosterol-5-en-3β,7β-diol (**66**), and stigmast-6β-hydroxyl-4-en-3-one (**68**).[10,37]

In general, *Glochidion* saponins **69-99** have been structurally formulated by a combination of aglycone oleanane and glycone at carbon C-3 (Table 1 and Figure 2).[10,12,13,30,33–37,40–44,47] Glucopyranose and arabinopyranose are the main units in glycone parts. Remarkably, all the isolated saponins were new in the literature except for daucosterol (**70**) and pedunculoside (**99**). A new triterpene saponin **69**, namely assamicoside A, was isolated from the 95% ethanol extract of *G. assamicum* aerial parts.[37] Various species were found to contain compound **70**, eg, *G. heyneanum* aerial parts, *G. multiloculare* aerial parts, *G. obliquum* leaves, *G. puberum* aerial parts, and *G. wrightii* stems and leaves.[10,30,35,36,40] Glochidioside (**71**), and glochidiosides N and Q (**72-73**) were other triterpene saponins isolated from the acolholic extract of *G. heyneanum* aerial parts.[30,41] Five new saponins glochieriosides A-E (**74-78**) were among phytochemicals present in Vietnamese *G. eriocarpum* aerial parts.[33,34] In the same manner, serial new saponins glomerulosides A-H (**79-86**) and glomerulosides I-II (**87-88**) have been purified from Vietnamese *G. glomerulatum* leaf extract.[12,13] The last serial new saponins hirsutosides A-E (**89-93**) and puberosides A-E (**94-98**) presented in the alcoholic extracts of *G. hirsutum* leaves and *G. puberum* aerial parts, respectively.[42–44]

Lignans, Flavonoids, and Mono-Phenols

About forty lignans have been isolated and structurally identified, and they can be categorized as aryltetralins **100-106**,[1,45,46] furan **107**,[1,10] furofurans **108-114**,[1,10,15,37,40,47] phenylpropanoids **115-123**,[1,35,46,48] benzofurans **124-139**,[1,45,48,49] and lignanoid **140**[21] (Table 1 and Figure 3).

Taking aryltetralins type lignan **100-106** into consideration, almost all of them were derivatives of isolariciresinol. The water-soluble extract of *G. wilsonii* roots was composed of four known metabolites (+)-isolariciresinol (**100**), (+)-isolariciresinol 3a-*O*-β-D-glucopyranoside (**104**), (+)-isolariciresinol 9'-*O*-β-D-xylopyranoside (**105**), and (–)-secoisol ariciresinol (**106**).[1] (+)-Isolariciresinol 2a-*O*-β-D-glucopyranoside (**101**) was a new aryltetralin found in *G. zeylanicum* leaves, but its isomer **102** was first isolated from *G. rubrum* leaves.[45,46] So far compounds **101-103** were proved to be presented in the leaves of *G. rubrum* leaves.[46] (+)-Laricerisnol (**107**) is a unique furan-type ligan found in both *G. wilsonii* roots, and *G. wrightii* stems and leaves.[1,10]

A total of seven furofuran-type lignans **108-114** were summarized, in which (+)-pinoresinol (**112**) and (+)-syringaresinol (**113**) were isolated frequently. For instance, compound **113** was recorded in *G. obliquum* leaves, *G. puberum* aerial parts, *G. wilsonii* roots, and *G. wrightii* stems and leaves.[1,10,15,40] In

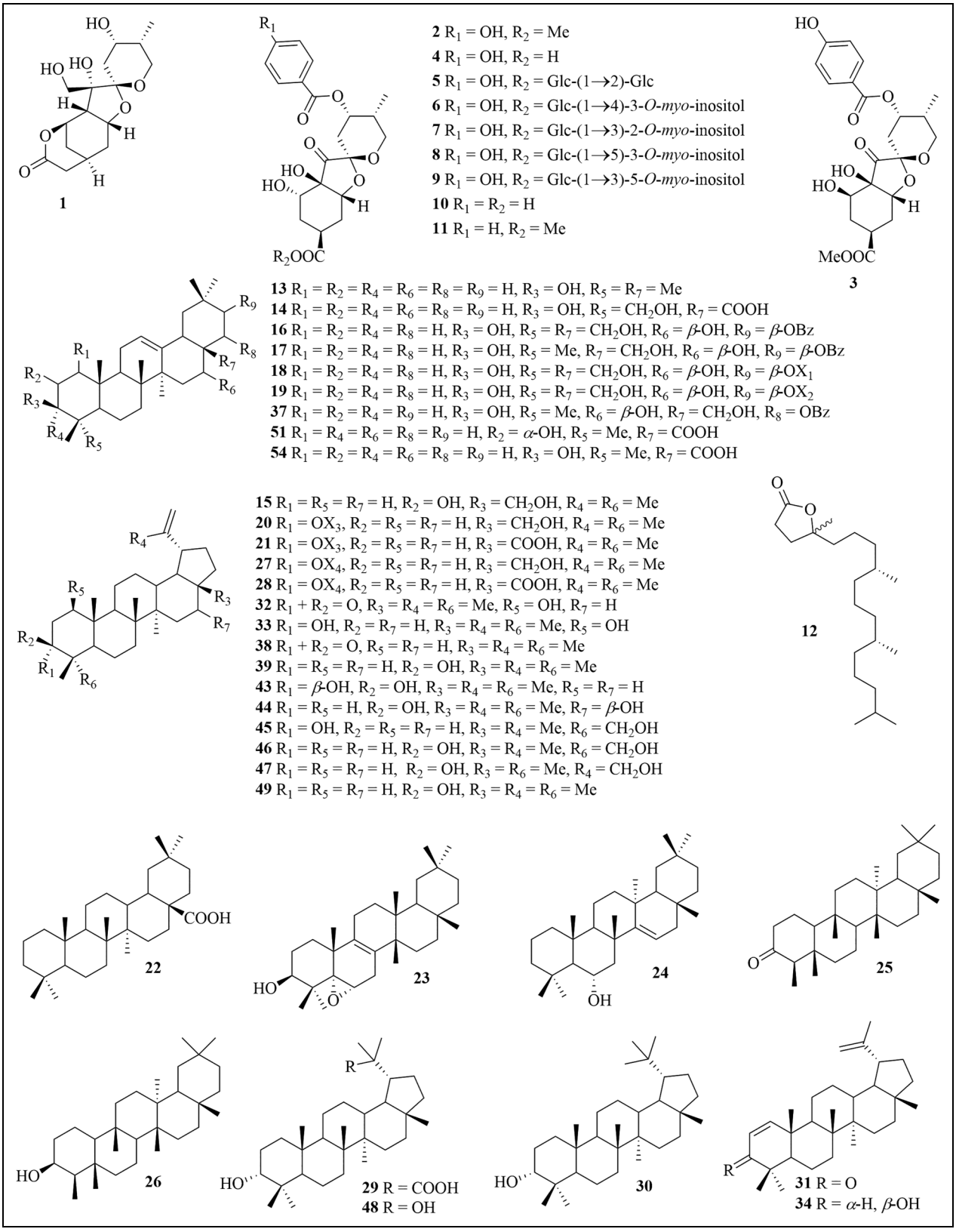

Figure 1. Terpenoids and sterols from *Glochidion*. (continued)

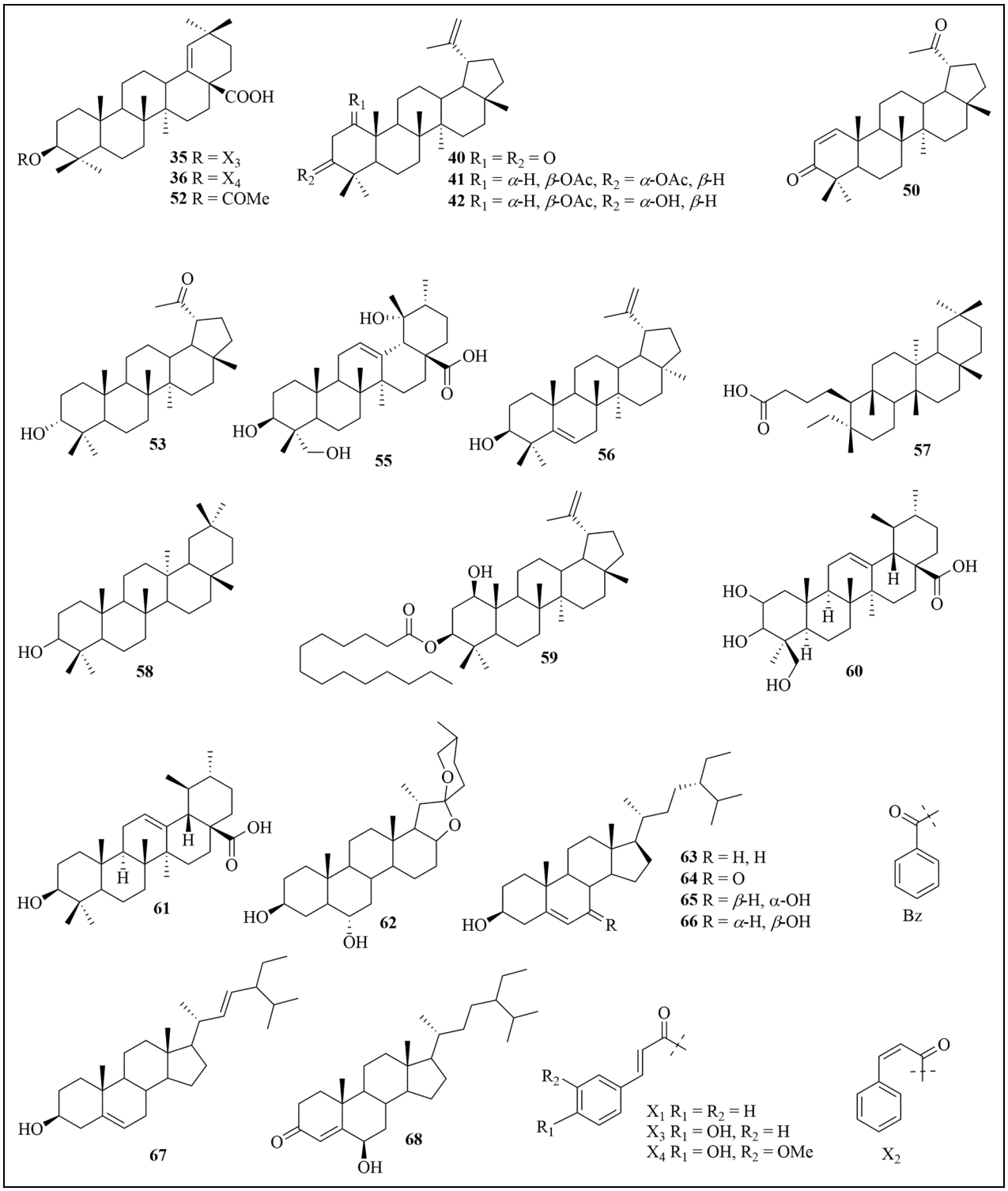

Figure 1. Continued.

the meantime, balanophonin B (**108**), clemaphenol A (**109**), 4,4'-dimethoxy-3'-hydroxy-7,9':7′,9-diepoxylignan-3-*O*-*β*-*D*-glucopyranoside (**110**), and yangambin (**114**) were isolated from the genus *Glochidion* for the first time.[1,47]

A report published by Gao and partners indicated that *G. wilsonii* plant is thought to be a reservoir of lignans. Its roots contained six phenylpropanoids type lignan dihydroconiferyl alcohol (**115**), (*E*)-4-hydroxycinnamyl alcohol-4-*O*-*β*-D-

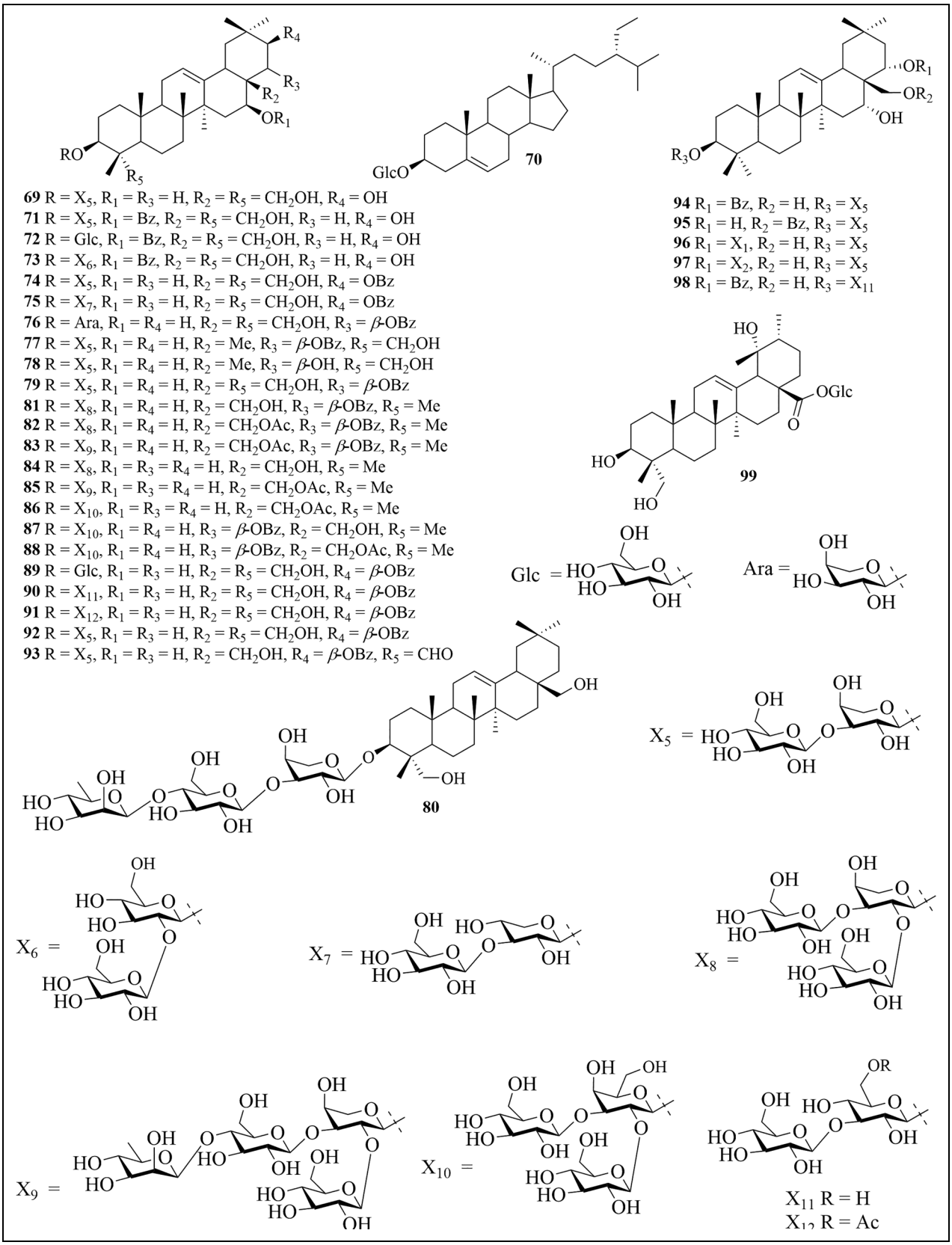

Figure 2. Saponins from *Glochidion*.

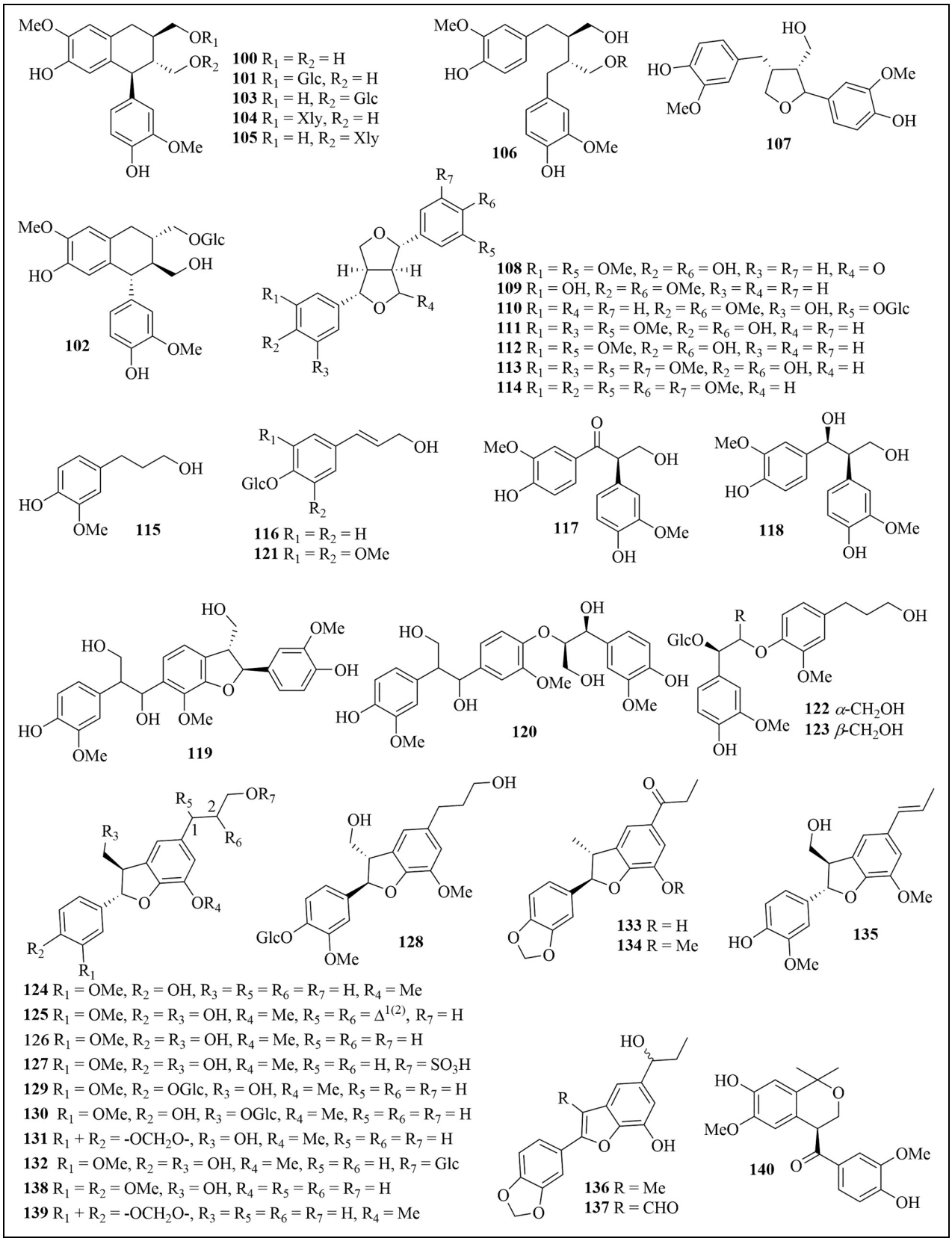

Figure 3. Lignans from *Glochidion*.

glucopyranoside (**116**), evofolin B (**117**), *rel*-(1*R*,2*S*)-1,2-*bis*(4-hydroxy-3-methoxy-phenyl)-1,3-propanediol (**118**), and leptolepisols C-D (**119-120**).[1] Another well-known phenylpropanoid, namely syringin (**121**), was found in both *G. eriocarpum* whole plant and *G. obliquum* leaves.[35,48] It is marked that (7*R*,8*S*)-4,7,9,9'-tetrahydroxy-3,3'-dimethoxy-8-*O*-4'-neolignan 7-*O*-*β*-D-glucopyranoside (**122**) and (7*R*,8*R*)-4,7,9,9'-tetrahydroxy-3,3'-dimethoxy-8-*O*-4'-neolignan 7-*O*-*β*-D-glucopyranoside (**123**) were two new phenylpropanoids appeared in the leaves of *G. rubrum*.[46]

Benzofurans type lignan were also characteristics of *G. wilsonii*, in which alcoholic extract of its roots consisted of five new derivatives glochiwilsonises A-E (**133-137**), together with six known ones 9'-dehydro-valadion F (**124**), dehydrodiconiferyl alcohol (**125**), dihydrodehydrodiconiferyl alcohol (**126**), 9,9'-dihydroxy-3,4-methylenedioxy-3'-methoxy [7-*O*-4',8-5'] neolignan (**131**), 4-*O*-methylcedrusin (**138**), and phyllnirurin (**139**).[1] The remaining benzofurans, including two new metabolites dihydrodehydrodiconiferyl alcohol 9'-*O*-sulfate (**127**) and glochidioboside (**132**), and three known analogs 7*R*,8*S*-dihydrodehydrodiconiferyl alcohol 4-*O*-*β*-D-glucopyranoside (**128**), 7*S*,8*R*-dihydrodehydrodiconiferyl alcohol 4-*O*-*β*-D-glucopyranoside (**129**), and dihydrodehydrodiconiferyl alcohol 9-*O*-*β*-D-glucopyranoside (**130**), which were found in *G. eriocarpum* whole plant and/or *G. zeylanicum* leaves[45,48] (Table 1). In the last case, novel and unique lignanoid glochinin A (**140**) was extracted from the 75% ethanol extract of *G. puberum* aerial parts.[21]

As shown in Table 1 and Figure 4, *Glochidion* flavonoids were found to contain the subclasses of flavones **141-147**,[6,15,35,40,50] flavans **148-153**,[50–52] flavanones **154-159**,[10,53] and chalcone **160**.[51] Together with 8-*C*-glucosylated flavone 6''-*O*-acetylorientin (**141**), *G. obliquum* leaves was reported to contain new 6-*O*-glycosylated flavone globlin A (**142**).[15,35] In the search for cytotoxic agents from natural plants, three well-known flavones isoorientin (**143**), orientin (**145**), and vitexin (**146**) were isolated from the methanol extract of *G. hypoleucum* leaves.[6] Compound **146** was further detected in *G. obliquum* leaves, *G. puberum* aerial parts, and *G. zeylanicum* leaves.[15,35,40,50] By silica gel and Sephadex-LH20 chromatographic separation, two other known flavones isovitexin (**144**) and its 7-*O*-xyloside (**145**) were purified from the ethanol extract of *G. hirsutum* stems.[7]

Among the isolated flavans **148-153**, compounds **149-153** were new secondary metabolites with the same absolute configuration at carbons C-2 and C-3. Glochiflavanosides A-D (**149-152**) were fractionated from the methanol extract of *G. zeylanicum* leaves, whereas the bulk metabolite glochiin C_1 (**153**) originated from the aqueous acetone homogenate of *G. rubrum* leaves.[50,52] Besides the known flavanone (2*R*,3*R*)-dihydromyricetin (**158**), four new analogs (2*R*,3*R*)-dihydromyricetin-4'-*O*-(3''-*O*-methyl)-gallate (**154**), (2*R*,3*R*)-dihydromyricetin-3'-*O*-(3''-*O*-methyl)-gallate (**155**), (2*R*,3*R*)-dihydromyricetin-4'-*O*-gallate (**156**), and (2*R*,3*R*)-dihydromyricetin-3'-*O*-gallate (**157**) had been observed in *G. sumatranum* leaves and twigs.[53] The last flavanone narigenin (**159**) arose from *G. wrightii* stems and leaves.[10] Chalcone **160**, namely phloretin 4'-*O*-*β*-D-glucopyranoside, was among the isolates present in *G. acuminatum* leaves.[51]

Mono-phenols are widely found in higher plants, as well as they appear in the form of mono-phenol or their precursors. *Mono*-phenols exhibited a great number of pharmacological activities such as antioxidant, antimicrobial, antiviral, and antiinflammatory activities.[63–65] It turns out that the genus *Glochidion* is also rich in this type with more than twenty compounds **161-183** being isolated (Table 1 and Figure 4).[1,6,7,35,37,40,46,48,49,51,52,54,55] *G. eriocarpum* whole plant, *G. hirsutum* stems, *G. obliquum* leaves, *G. obovatum* leaves, *G. rubrum* leaves, and *G. wilsonii* roots were recorded to encompass bergenin (**161**).[1,7,35,46,48,49] In addition, 4-*O*-ethylgallic acid (**163**), gallic acid (**166**), glochidacuminoside A (**168**), methyl gallate (**177**), and 24,6-trimethoxyphenol-1-*O*-*β*-D-glucoside (**182**) were found in two or three species, whereas the remaining *mono*-phenols were isolated from the genus *Glochidion* for the first time (Table 1). Significantly, several compounds were identified to be new derivatives. Glochidacuminoside A (**168**), which was a new *mono*-phenol isolated from *G. acuminatum* leaves, existed as a salt of several metal ions.[50] Methyl 2-(2-hydroxyphenyl) acetate *β*-D-glucopyranoside (**175**) was another new *mono*-phenol found in *G. acuminatum* leaves.[51] The leaf extract of *G. rubrum* was associated with the presence of three new phytochemicals glochiins M_1 and M2 (**169-170**) and tachioside 2'-*O*-4''-*O*-methylgallate (**181**).[46,52] Two last new *mono*-phenolic compounds glochiwilsophenoside (**171**) and 2-*β*-D-glucopyranosyloxy-4-methoxy-6-hydroxy-isovalero-phenone (**172**) were fractionated from the methanol extract of *G. wilsonii* roots and *G. eriocarpum* whole plant, respectively.[1,48]

Megastigmanes, Butenolides, and Glycosides

Phytochemical studies of *Glochidion* species further reported the presence of megastigmanes **184-199** (Figure 5).[14,37,46,48,49,56,57] To date, this chemical class can be found in *G. assamicum*, *G. obliquum*, *G. rubrum*, and *G. zeylanicum*, especially *G. eriocarpum* (Table 1). Besides the known compounds, *G. obliquum* leaves collected from Vietnam, have been reported to compose of an unusual novel megastigmane 6*β*,9*β*:9,13-diepoxymegastig-4-en-3*β*-ol (**187**).[14] Based on chemical and spectroscopic methods, glochidionionosides A-D (**189-192**), (3*S*,5*R*,6*R*,7*E*,9*S*)-megastigman-7-ene-3,5,6,9-tetrol 3-*O*-*β*-D-glucopyranoside (**197**), and (3*S*,5*R*,6*R*,7*E*,9*S*)-megastigman-7-ene-3,5,6,9-tetrol 9-*O*-*β*-D-glucopyranoside (**198**) were confirmed to be six new megastigmane glycosides, and they were derived from Japanese *G. zeylanicum* leaves.[56,57]

It matches well with previous evidence since butenolides were also characteristic compounds of Euphorbiaceae plants. Regarding the genus *Glochidion*, more than ten isolates **200-211** have been summarized (Table 1 and Figure 5).[1,51,54,58,59] In addition to the known metabolites (+)-aquilegiolide (**200**) and (−)-loliolide (**209**), and (+)-menisdaurilide (**210**), two new butenolides isoglochidiolide (**201**) and glochidiolide (**202**) were separated from Japanese *Glochidion* species, *G. acuminatum*

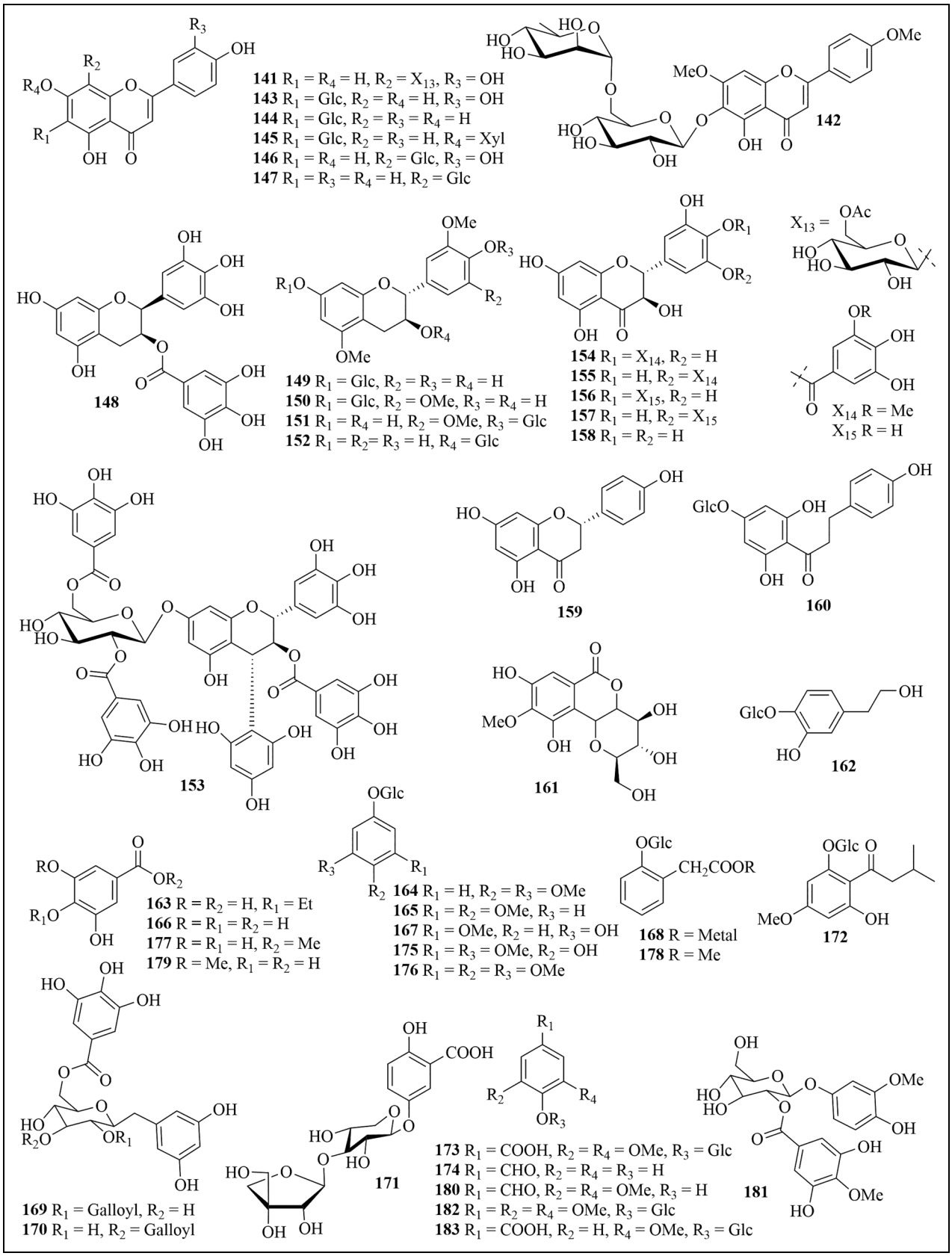

Figure 4. Flavonoids and *mono*-phenols from *Glochidion*.

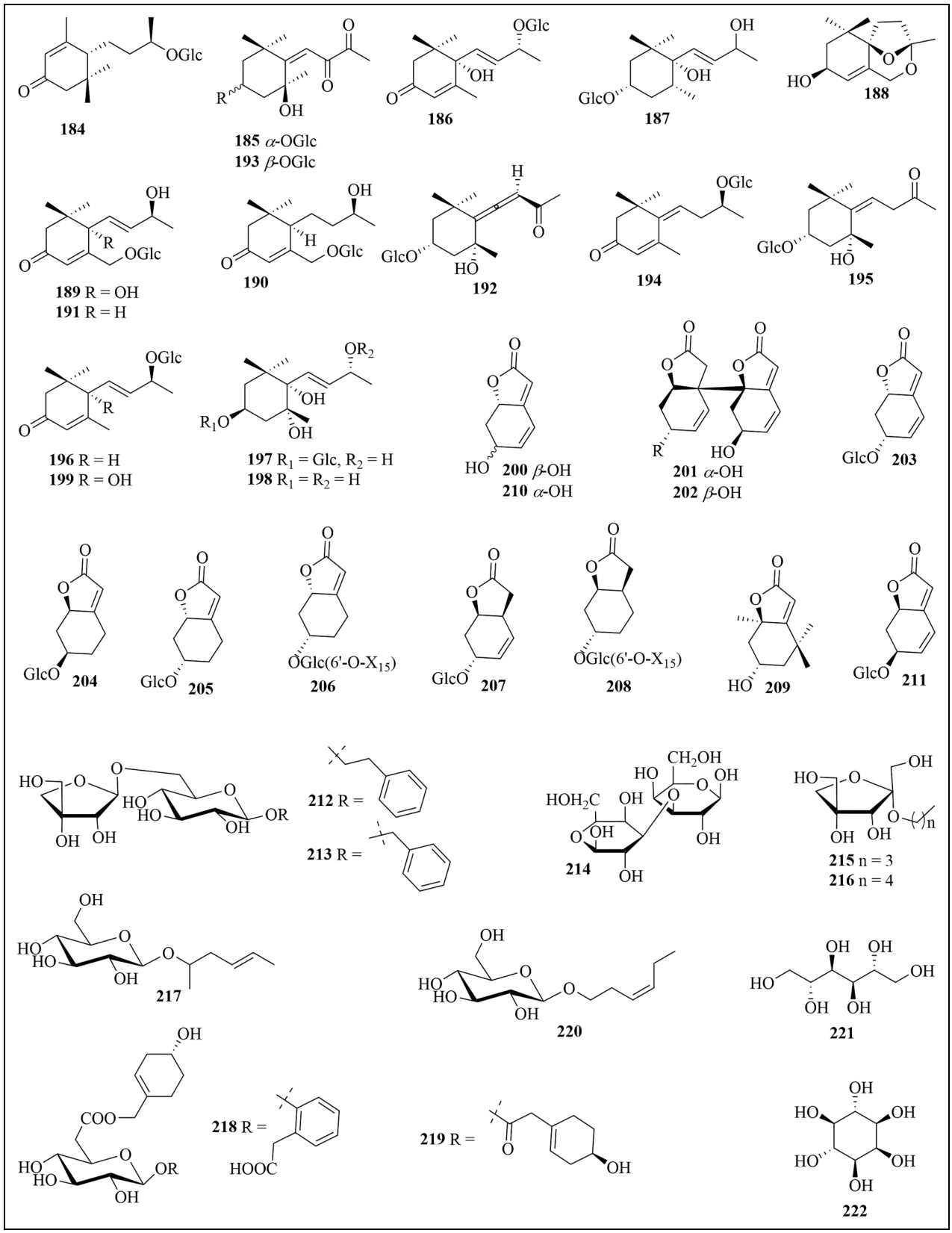

Figure 5. Megastigmanes, butenolides, and glycosides from *Glochidion*.

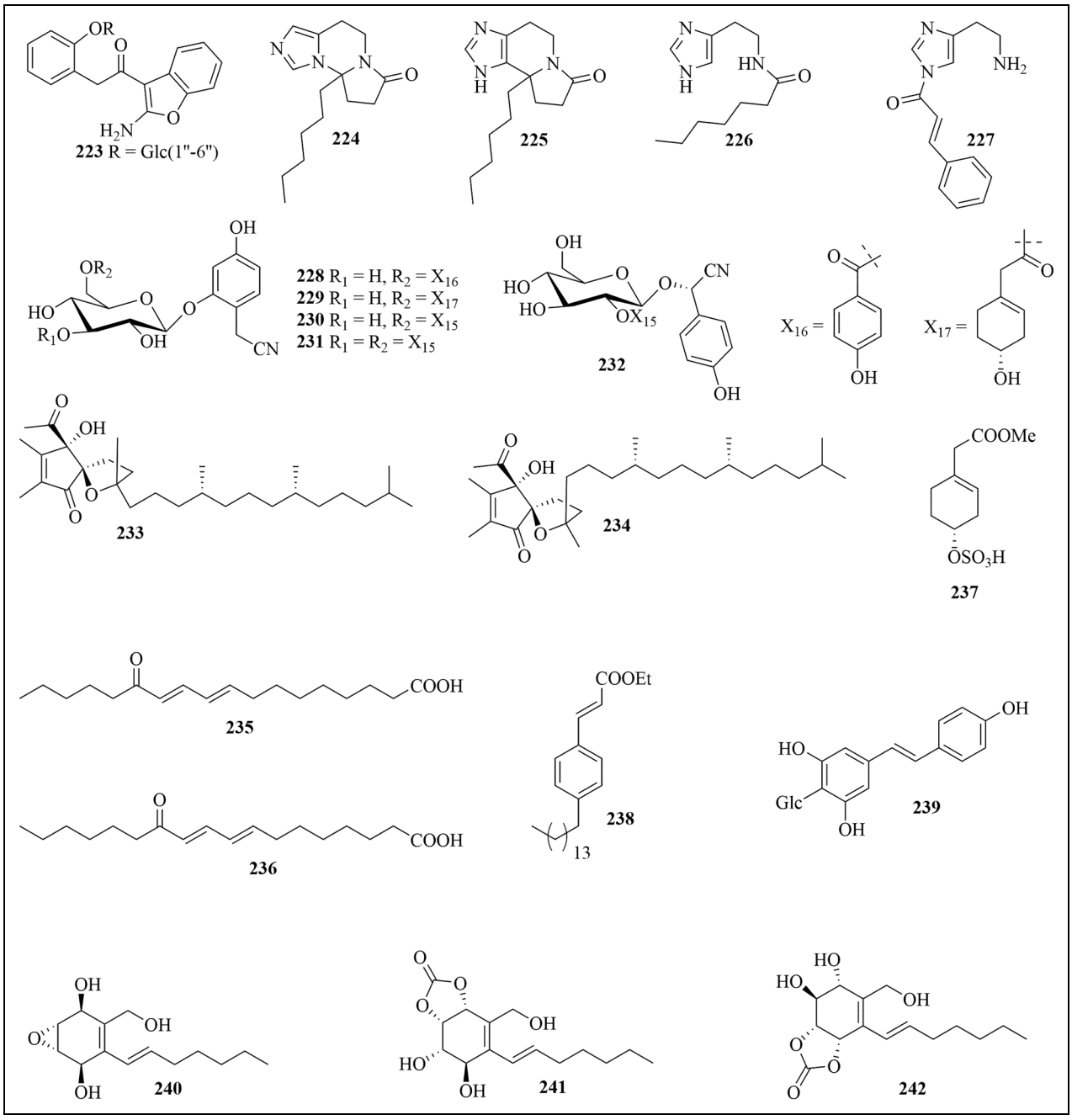

Figure 6. Alkaloids, cyanogens, tocopherols, fatty acids, and others from *Glochidion*.

leaves.[49,51,54] Six new glycosylated isolates glochidionolactones A-F (**203-208**) and the known analog phyllanthurinolactone (**211**) were also purified from the methanol extract of another Japanese *Glochidion* species, *G. zeylanicum* leaves.[59]

Glochidion glycosides **212-222** appeared in free forms or in combination with aliphatic aglycones (Table 1 and Figure 5).[7,30,35,37,40,46,54] Glycoside derivatives can be found in aerial parts of several *Glochidion* plants, such as *G. assamicum*, *G. heyneanum*, *G. hirsutum*, *G. puberum*, *G. obliquum*, and *G. rubrum* (Table 1). Among these glycosides, the isolated compounds **218-219** were identified to be two new compounds, which were trivially named glochidacuminosides B-C, and were extracted from the 95% aqueous fraction of *G. acuminatum* leaves.[54]

Alkaloids, Cyanogens, Tocopherols, Fatty Acids, and Others

Alkaloids are the next phytochemical class found in the genus *Glochidion* (Table 1 and Figure 6). Acuminaminoside (**223**) represented an alkaloidal glycoside containing an unusual dimeric

phenylethane backbone, which was isolated from the methanol extract of *G. acuminatum* leaves for the first time.[54] Three new histamine alkaloids glochidine (**224**), glochidicine (**225**), and *N*α-(4-oxodecanoyl)-histamine (**226**), along with a known analog N^{α}-cinnamoylhistamine (**227**) were detected in a New Guinea *Glochidion* plant, *G. philippicum* leaves.[60]

Natural compounds bearing the CN functional group were also present in *Glochidion* plants (Table 1 and Figure 6). Significantly, all the isolated cyanogen glycosides, consisting of 2-(2,4-dihydroxyphenyl) acetonitrile 2-*O*-*β*-D-glucopyranoside 6'-*O*-p-hydroxybenzoate (**228**), 2-(2,4-dihydroxyphenyl) acetonitrile 2-*O*-*β*-D-glucopyranoside 6'-*O*-(S)-2-(4-hydrocyclohex-1-en-1-yl)acetate (**229**), 2-(2,4-dihydroxyphenyl) acetonitrile 2-*O*-*β*-D-glucopyranoside 6'-*O*-gallate (**230**), 2-(2,4-dihydroxyphenyl) acetonitrile 2-*O*-*β*-D-glucopyranoside 3',6'-*O*-digallate (**231**), and glochidacuminoside D (**232**) were new in literature, and were only found in *G. acuminatum* leaves.

The chromatographic procedure of the alcoholic extract of *G. wrightii* stems and leaves resulted in the isolation of two known tocopherols *α*-tocospiro A (**233**) and *β*-tocospiro B (**234**), whereas two known fatty acids (9*E*,11*E*)-13-*oxo*-9,11-octadecadienoic acid (**235**) and rabdosia acid A (**236**) were derived from *G. wilsonii* roots (Table 1 and Figure 6).[1,10]

Phytochemical studies aided by the NMR spectral data also revealed the presence of three other phytochemicals (*S*)-methyl 2-[4-sulfooxycyclohex-1-en-1-yl] acetate (**237**), *p*-pentadecayl ethyl cinnamate (**238**), and resveratrol-12-C-*β*-glucopyranoside (**239**) in *G. acuminatum* leaves, *G. velutinum* leaves, and *G. wilsonii* roots, respectively.[1,51,61] Among them, compounds **237-238** were new in nature. Chromatographic column procedure to the methanol extract of the endophytic fungus *Eupenicillium* sp. parasited-*G. ferdinandi* can lead to the separation of two new polyketides phomoxins B-C (**241-242**), and a known analog eupenoxide (**240**).[62]

the GC/LC-MS, and Other Phytochemical Analyses

Plants in the genus *Glochidion* are also the main object of essential oil studies. Following the GC-MS analysis, linalool (59.76%) and (*E*)-2-hexen-1-ol (7.76%) can be seen as the main agents of *G. sphaerogynum* male flowers.[17] (*E*)-2-Nonenal (36.6%) and (*E*)-2-nonen-1-ol (14.14%) accounted for 36.6 and 14.14% of *G. hirsutum* male flowers, respectively.[17] *G. zeylanicum* male flowers were dominated by (*E*)-2-nonenal (23.5%) and (*E*)-2-nonen-1-ol (11.17%), whereas (*E*)-β-ocinene (42.6%) was predominant in *G. eriocarpum* female flowers.[17] In another study, (*E*)-β-ocinene reached up to 25.66 and 94.34% in the flowers of *G. rubrum* and *G. acuminatum*, respectively.[16] (*E*)-Linalool oxide (furanoid) fluctuated from 45.88 to 73.19% in the flowers of *G. lanceolatum*, *G. obovatum*, and *G. rubrum*.[16] The GC-MS analysis identified the main compounds of *G. sphaerogynum* bark methanol extract as aliphatic compounds, whereas the atomic absorption spectrometry (ASS) analysis affirmed the concentration of metals Na and Ca at 8–10 ppm.[66] The phytochemical profile of *G. velutinum* leaf extracts using LC-MS/MS-based molecular networking was associated with the presence of *mono*-phenols and flavonoids.[67] For instance, its *n*-butanol fraction contained quinic acid, trehalose, isovitexin, hyperoside, and luteolin 4'-*O*-glucoside.[67]

Total phenolic content (TPC) and total flavonoid content (TFC) in the methanol extract of *G. ellipticum* leaves were found to be 252.67 mg gallic acid equivalent (GAE)/100 g dried weight (DW) and 179.58 mg catechin equivalent (CE)/100 DW, and were better than those in the chloroform extract (136.34 mg GAE/100 g DW and 78.79 mg CE/100 g DW) and petroleum extract (25.86 mg GAE/100 g DW and 14.71 mg CE/100 g DW).[68] The TPC and TFC values of *G. hirsutum* leaf ethanol extract were 11.57 mg GAE/g DW and 3.02 mg CE/g DW, respectively, whereas those of *G. sphaerogynum* leaf ethanol extract were 4.83 mg GAE/g DW and 1.93 mg CE/g DW.[69] In another report, the TPC and TFC values of *G. zeylanicum* leaf methanol extract were 320.14 mg GAE/g DW, and 52.54 mg quercetin equivalent (QE)/g DW, respectively.[70] Cyanidin and anthocyanidin amounts in *G. perakense* young leaves were about 13.29 mg/100 g fresh weight (FW), whereas their TPC value was about 4762.76 mg GAE/100 g FW.[71] *G. perakense* young leaves were also rich in β-carotene, lutein, and vitamins C and E.[71]

Pharmacological Activities

Cytotoxicity

New sesquiterpenoid glochiwilsonoside A (**7**) inhibited the proliferation of A-549 cancer cells with the IC_{50} value of 34.5 μM.[1] Two triterpenoids lup-20(29)-ene-1*β*,3*β*-diol (**43**), and lup-20(29)-ene-3*β*,23-diol (**46**), especially two new saponins glochieriosides A-B (**74-75**) exhibited cytotoxicity against four cancer cell lines HL-60, HT-29, MCF-7, and SK-OV-3 with the IC_{50} values of 5.5-67.0 μM, but triterpenoid glochidone (**34**) failed to do so ($IC_{50} > 100$ μM, inactive).[33] The difference in results between two saponins may be due to a great role of the glycone part at carbinol carbon C-3.

Triterpenoids **32-33**, and **45** had strong inhibitory effects against three cancer cell lines MCF-7, NCI-H460, and SF-268 ($GI_{50} \leq 20$ μM), triterpenoid **49** was less active ($GI_{50} > 50$ μM).[32] Triterpenoid **43** only moderately affected MCF-7 with the GI_{50} value of 79.2 μM, while compound **43**, once again, was found to be inactive.[32] The functional groups at carbon C-3 were responsible for the differential results of compounds **32-33** and **43**, while the difference among **32-33** and **45** was deduced from the functional groups at carbons C-3 and C-24.[32] As we know, the capability to suppress Epstein-Barr virus early antigen (EBV-EA) activation by tumor promoters correlated with their capability to inhibit tumor enhancement. Triterpenoids **32-34**, and **43** exhibited significant inhibitory effects on EBV-EA activation induced by 12-*O*-tetradecanoylphorbol 13-acetate (TPA), which were better than the standard curcumin (IC_{50} 343 mol ratio/32 pmol TPA).[31]

A publication in 2023 revealed that new triterpenoid **36**, and its known analogs **15**, **21**, **32-33**, and **52** showed the IC_{50} values of 0.80–2.99 μM lower than that of the standard 5-fluorouracil

(IC_{50} 3.79 μM).[38] In addition, anticancer mechanism of compound **36** is due to its endoplasmic reticulum stress-mediated apoptosis and enhancement of the sensitivity of HCT-16 cells to 5-fluorouracil.[38] Among tested compounds, only triterpenoid rotundic acid (**55**) was cytotoxic against three cancer cell lines Daoy, HepG2, MCF-7, and HeLa with the ED_{50} values of 24.67–29.43 μM, when mitomycin was used as a positive control (IC_{50} 0.21–0.30 μM.[35]

Glochidion saponins are the next chemical class used for cytotoxic examinations. Triterpene saponins **74-77** having a benzoyl group at carbon C-22 generated the IC_{50} values of less than 6.33 μM in cytotoxic assay against HL-60 and HCT-116 cancer cells, which were better than analog **78** without a benzoyl group at carbon C-22 (IC_{50} 29.62-34.00 μM), and the standard mitoxantrone (IC_{50} 7.23-8.40 μM).[72] Further evidence revealed that the potential saponins **74-77** induced apoptosis in HCT-116 cells by phosphorylation of ERK and p38.[72]

Serial new triterpene saponins glomerulosides A-H (**79-86**) exerted the IC_{50} values of 8.2–94.9 μM against four cancer cell lines A-549, HT-29, OVCAR, and MCF-7.[12] Among these, compound **80** without the functional groups at carbons C-16 and C-22 remarkably controlled the growth of A-549 and HT-29 cancer cells with the IC_{50} values of 9.7 and 7.5 μM.[12] In contrast to compounds **84-86**, compounds **81** and **83** having a benzoyloxy group at carbon C-22 exhibited strong activity against A-549, HT-29, and OVCAR cancer cells with the IC_{50} values of 5.9-9.8 μM.[12]

In another report, four new triterpenoid saponins hirsutosides A-B and D-E (**89-90** and **92-93**) possessed the IC_{50} values of 3.4–10.2 μM against four cancer cell lines HepG-2, A-549, MCF-7, and SW-626, whereas those of hirsutoside C (**91**) were 47.0–54.4 μM.[42] Considering structure activity relationship among metabolites **89–91**, compound **90** with an additional sugar unit at Glc C(3'') showed stronger cytotoxicity, but with the introduction of the AcO group to Glc C(6'') of compound **91**, activity will be decreased.

Both the methanol extract of *G. velutinum* leaves and its *n*-hexane, chloroform, ethyl acetate, *n*-butanol, and aqueous fractions were reported to show cytotoxicity towards two cancer cell lines MCF-7 and PC-3 (Table 2).[67] At the same dose of 20 mg/kg, i.p., the methanol extract and its petroleum ether, carbon tetrachloride, and chloroform fractions of *G. multiloculare* stem barks increased the survival time of mice bearing EAC (Ehrlich's ascites carcinoma) from 21 to 27 days, compared to the control group (20 days).[73] The effect was also associated with a restoration of heamoglobin, a remarkable decrease in red blood cells, and an increase in white blood cells.[73]

Antioxidative Activity

It was noted that flavones **143** and **146** and *mono*-phenols **166** and **177** may become potential agents for antioxidative drug development since they are comparable to the positive control ascorbic acid (IC_{50} 12.5 μg/mL) to scavenge 2,2-diphenyl-1-picrylhydrazyl (DPPH) radicals.[6] In another report, new cinnamate derivative **238** exhibited antioxidative activity to capture DPPH radicals with the IC_{50} value of 302.5 μg/mL.[61]

The methanol extract of *G. sphaerogynum* barks scavenged DPPH radicals with the IC_{50} value of 37.4479 μg/mL, in comparison with that of the methanol extract of *G. hypoleucum* leaves (IC_{50} 40 μg/mL.[6,66] The DPPH radical quenching activity of the 95% ethanol extracts of *G. hirsutum* leaves and *G. sphaerogynum* leaves corresponds to 181.74 and 42.19 μg AAE (ascorbic acid equivalent)/g DW.[69] *G. zeylanicum* leaf methanol extract strongly quenched DPPH and 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) radicals with the IC_{50} values of 6.56 and 3.76 μg/mL, respectively.[70] The 80% ethanol extract of *G. wallichianum* leaves caused antioxidative activity against DPPH, and ABTS radicals and ferric reducing antioxidant power (FRAP) activity with 2.3, 1.9, and 1.1 mmole trolox equivalent (TE)/g DW, respectively.[74] In addition, this extract at the concentration of 0.01% could significantly maintain oxidative stability and physicochemical quality of the cooked sausage model system, which were comparable to or better than those of the standard butylated hydroxyl toluene (BHT).[74] The methanol extract of *G. multiloculare* barks containing about 100 mg GAE/mg DW caused the IC_{50} value of 16.46 μg/mL, which was stronger than the positive control BHT (IC_{50} 20.45 μg/mL) against DPPH radicals.[75]

Antimicrobial Activity

Glochidol (**31**) has shown antimicrobial activity against the bacteria *Bacillus subtilis* and MRSA (*methicillin-resistant Staphylococcus aureus*) with the same minimum inhibitory concentration (MIC) value of 128 μM.[76] The synergistic effect in combination of triterpenoid 31 and the standard tetracycline *against Escherichia coli* and *Pseudomonas aerugiosa* was accompanied by the corresponding fractional inhibitory concentration index (FICI) values of 0.5156 and 0.5313, and a decrease in time-kill of 4.0 and 6.0 h, respectively.[76] *Mono*-phenol methyl gallate (**177**) exerted the MIC of 50 μg/mL and MBC of 100 μg/mL against MRSA.[55]

Glochidiol (**32**) was comparable with the standard tetracycline in antibacterial assay against bacterium *P. aeruginosa* with the same MIC value of 64 μM.[39] Meanwhile, the MIC values of 512–2048 μM were assignable to other tested triterpenoids **33-34**, **45** and **49**.[39] Additionally, triterpenoid **45** also significantly inhibited the growth of bacterium *E. coli* with the MIC value of 512 μM.[39]

New flavanones **154**, **156**, and known analog **158** possessed inhibitory percentages of 71, 56, and 52% to *P. aeruginosa*, respectively.[53] Compounds **154** and **156** were also found to suppress *S. aureus* up to 49% and 70%, respectively. The difference among these flavanones can be explained by the functional groups at carbons C-3' and C-4'.

Natural metabolite **238** was also responsible for antimicrobial activity against a panel of bacterial strains *B. cereus, S. aureus, Enterococcus faecalis, E. coli* EPEC, *E. coli* ETEC, *E. coli* ATCC,

Klebsiella oxytoca, *K. michiganensis*, *Salmonella typhi*, and *Proteus vulgaris* with the inhibition zone (IZ) values of 5–12 mm.[61]

In general, the use of halogenated solvents should be appropriate since the chloform extract of *G. multiloculare* barks with the IZ values of 9–12 mm was better than other typical extracts in antimicrobial experiments against *B. cerus*, *B. megaterium*, *B. subtilis*, *Sarcina lutea*, *E. coli*, *P. aeruginosa*, *S. typhi*, *Shigella dysenteriae*, *Sh. boydii*, *Vibrio mimicus*, *V. parahemolyticus*, *Candida albicans*, *Aspergillus niger*, and *Sacharomyces cerevaceae*.[77]

The silver nanoparticles synthesized from *G. candolleanum* leaves inhibited the growth of bacteria *Salmonella enterica* and *P. aeruginosa* with the IZ values of 12.2 and 11.8 mm, respectively.[78] The ethanol extract of *G. puberum* roots monitored the proliferation of *B. subtitis* and *P. aeruginosa* with the corresponding MIC values of 100 and 200 μg/mL, but was inactive to bacteria *E. coli* and *S. aureus* (MIC > 200 μg/mL).[79]

Antiinflammatory Activity

Sesquiterpenoid **7** displayed an antiinflammatory effect in lipopolysaccharide (LPS)-stimulated nitric oxide (NO) production with the IC_{50} value of 16.0 μM.[1] As shown in Table 2, the isolated compounds 24, 55, 58, 99, 121, 142, 147, and 161 from Vietnamese G. obliquum leaves exhibited anti-inflammatory effects in LPS-stimulated inducible nitric oxide (iNOS) dependent NO production in microglial cells with the IC_{50} values of 39.5–98.4 μM.[35] However, only triterpenoids 55 and 58 inhibited NOX (NADPH oxidase)-dependent reactive oxygen species (ROS) production in microglial cells.[35]

The ethanol extract of G. thomsonii barks (250 and 500 mg/kg, p.o.) was able to protect against inflammation in two models of carrageenan-mediated paw edema and xylene-mediated ear edema in mice.[18] Besides anticancer activity, at the same dose of 100 mg/kg, i.p., the methanol extract and its petroleum ether, carbon tetrachloride, and chloroform fractions of *G. multiloculare* stem barks also exhibited antiinflammatory effect in carrageenan-induced paw edema in mice.[73]

An inflammatory bowel disease called ulcerative colitis makes your digestive system inflamed and produces ulcers, or sores.[92,93] The rectum and the innermost lining of your large intestine, commonly referred to as the colon, are affected by ulcerative colitis. For the majority of persons, symptoms typically appear gradually as opposed to abruptly. It turns out that the treatment of G. ellipticum leaf extracts (n-hexane, dichloromethane, and n-butanol), at the same dose of 200 mg/kg, p.o., could ameliorate DSS (dextran sulfate sodium)-stimulated colitis in mice via the nuclear factor-kappa B (NF-κB) signaling inhibition.[80] The expressions included reductions in NO, ROS, pro-inflammatory cytokines, iNOS, and cyclooxygenase-2 (COX-2).[80]

Antidiabetic Activity

The 95% ethanol extract of *G. hirsutum* leaves suppressed α-amylase and α-glucosidase enzymes with the IC_{50} values of 0.59–1.01 mg/mL, as compared with those of the 95% ethanol extract of *G. sphaerogynum* leaves (IC_{50} 2.21-2.84 mg/mL).[69]

The ethanol extract from a combination of *G. arborescens* leaves and *Cynometra ramiflora* leaves showed in vitro α-glucosidase inhibition with an IC_{50} value of 374.47 ppm, when acarbose was used as a positive control (IC_{50} 14.17 ppm).[81] The oral administration of *G. velutinum* leaf ethanol extract at the two doses of 200 and 400 mg/kg inhibited streptozotocin-nicotinamide stimulated type 2 diabetic mice by reducing glucose levels, and altering lipid, glutamic-oxaloacetic transaminase, and alanine aminotransferase levels.[82] At the same two doses, the aqueous extract of *G. zylanicum* roots possessed hypoglycemic activity by lowering blood glucose levels in mice, which was comparable to that of the standard glibenclamide at 10 mg/kg.[19] In the same manner, the aqueous extract of *G. velutinum* leaves significantly reduced blood glucose levels at the dose of 400 mg/kg, p.o. for 15-day treatment.[20]

Antiurolithiatic, and Antidiarrheal Activities

The methanol extract of *G. velutinium* leaves (500 mg/kg, p.o.) established antiurolithiatic action via suppression of the CAOX crystal formation in calculogenic mice.[83] The obtained results involved decreases in the levels of calcium, phosphorus, and oxalate in both the urine and kidney, and the levels of BUN, creatinine, and uric acid in the serum, especially a reduction of stone-forming constituents in the kidney.[83]

The ethanol extract of *G. thomsonii* barks at two doses of 250 and 500 mg/kg, p.o., has a marked antidiarrheal effect again the episode number of defecation and diarrheal feces.[84] This extract at a higher dose protected against castor oil-induced diarrhea in mice by up to 54.47%, as well as reduced intestinal fluid accumulation by 51.6%.[84]

Analgesic, and Sedative Activities

From Table 2, at the same dose of 100 mg/kg, i.p., the methanol extract and its petroleum ether, carbon tetrachloride, and chloroform fractions of *G. multiloculare* stem barks demonstrated inhibitions to acetic acid induced writhing in mice from 66.36 to 84.09%, when diclofenac-Na was used as a positive control (86.36% inhibition).[73]

Besides antiinflammatory effect, at the same doses of 250 and 500 mg/kg, the ethanol extract of G. thomsonii barks suppressed formalin-mediated paw licking and acetic acid-mediated writhing in mice, and two phases of formalin-induced paw-licking models of pain.[18] Sedative activity of the methanol extract of *G. multiloculare* leaves (200 mg/kg, p.o.) was accompanied by decreasing the locomotor activity of mice in hole cross, opening field, and prolonging the sleeping time.[5]

Neuroprotective Activity

The ethanol extract of *G. zeylanicum* leaves may be a viable therapy option for oxidative stress-induced Alzheimer's and

Table 2. Pharmacological Activities of Constituents from *Glochidion* species.

Compounds	Models	Effect	References
Cytotoxicity			
7	*In vitro*	IC_{50} = 34.5 μM/A-549	1
15	*In vitro*	IC_{50} = 1.89 μM/HCT-116	38
21	*In vitro*	IC_{50} = 1.16 μM/HCT-116	38
32	*In vitro*	IC_{50} = 2.4 μM/HCT-116 GI_{50} = 9.0 μM/MCF-7 GI_{50} = 4.9 μM/NCI-H460 GI_{50} = 9.8 μM/SF-268	32,38
32	*In vitro*	IC_{50} = 325 mol ratio/32 pmol TPA/EBV-EA induced by TPA	31
33	*In vitro*	IC_{50} = 2.91 μM/HCT-116 GI_{50} = 6.6 μM/MCF-7 GI_{50} = 7.5 μM/NCI-H460 GI_{50} = 9.7 μM/SF-268	32,38
33	*In vitro*	IC_{50} = 290 mol ratio/32 pmol TPA/EBV-EA induced by TPA	31
34	*In vitro*	IC_{50} = 341 mol ratio/32 pmol TPA/EBV-EA induced by TPA	31
36	*In vitro*	IC_{50} = 0.80 μM/HCT-116	38
43	*In vitro*	IC_{50} = 43.3 μM/HL-60 IC_{50} = 67.0 μM/HT-29 IC_{50} = 66.1 and 72.9 μM/MCF-7 IC_{50} = 48.0 μM/SK-OV-3	*32,33*
43	*In vitro*	IC_{50} = 300 mol ratio/32 pmol TPA/EBV-EA induced by TPA	31
45	*In vitro*	GI_{50} = 12.7 μM/MCF-7 GI_{50} = 17.9 μM/NCI-H460 and SF-268	32
46	*In vitro*	IC_{50} = 13.7 μM/HL-60 IC_{50} = 71.7 μM/HT-29 IC_{50} = 46.1 μM/MCF-7	*33*
49	*In vitro*	GI_{50} = 75.6 μM/MCF-7 GI_{50} = 86.1 μM/NCI-H460 GI_{50} = 80.9 μM/SF-268	32
52	*In vitro*	IC_{50} = 2.99 μM/HCT-116	38
55	*In vitro*	ED_{50} = 24.67 μM/Daoy ED_{50} = 29.22 μM/HepG2 ED_{50} = 29.43 μM/MCF-7	35
74	*In vitro*	IC_{50} = 1.16 μM/HCT-116 IC_{50} = 5.5 μM/HL-60 IC_{50} = 6.8 μM/HT-29 IC_{50} = 29.1 μM/MCF-7 IC_{50} = 22.7 μM/SK-OV-3	*33,72*
75	*In vitro*	IC_{50} = 0.41 μM/HCT-116 IC_{50} = 6.6 μM/HL-60 IC_{50} = 18.6 μM/HT-29 IC_{50} = 36.1 μM/MCF-7 IC_{50} = 16.0 μM/SK-OV-3	*33,72*
76	*In vitro*	IC_{50} = 5.07 μM/HL-60 IC_{50} = 0.94 μM/HCT-116	*72*
77	*In vitro*	IC_{50} = 6.33 μM/HL-60 IC_{50} = 0.73 μM/HCT-116	*72*
78	*In vitro*	IC_{50} = 29.62 μM/HL-60 IC_{50} = 34.00 μM/HCT-116	*72*
79	*In vitro*	IC_{50} = 41.0 μM/A-549 IC_{50} = 7.3 μM/HT-29 IC_{50} = 6.6 μM/OVCAR IC_{50} = 58.4 μM/MCF-7	*12*
80	*In vitro*	IC_{50} = 9.7 μM/A-549	*12*

(Continued)

Table 2. Continued

Compounds	Models	Effect	References
		IC_{50} = 7.5 μM/HT-29	
		IC_{50} = 41.5 μM/OVCAR	
		IC_{50} = 60.7 μM/MCF-7	
81	*In vitro*	IC_{50} = 7.9 μM/A-549	[12]
		IC_{50} = 5.9 μM/HT-29	
		IC_{50} = 9.8 μM/OVCAR	
		IC_{50} = 42.8 μM/MCF-7	
82	*In vitro*	IC_{50} = 58.2 μM/A-549	[12]
		IC_{50} = 49.3 μM/HT-29	
		IC_{50} = 59.4 μM/OVCAR	
		IC_{50} = 69.3 μM/MCF-7	
83	*In vitro*	IC_{50} = 8.2 μM/A-549	[12]
		IC_{50} = 5.9 μM/HT-29	
		IC_{50} = 8.6 μM/OVCAR	
		IC_{50} = 63.5 μM/MCF-7	
84	*In vitro*	IC_{50} = 94.9 μM/A-549	[12]
		IC_{50} = 45.0 μM/HT-29	
		IC_{50} = 34.1 μM/OVCAR	
		IC_{50} = 86.3 μM/MCF-7	
85	*In vitro*	IC_{50} = 58.1 μM/A-549	[12]
		IC_{50} = 49.1 μM/HT-29	
		IC_{50} = 45.8 μM/OVCAR	
		IC_{50} = 67.5 μM/MCF-7	
86	*In vitro*	IC_{50} = 51.7 μM/A-549	[12]
		IC_{50} = 58.7 μM/HT-29	
		IC_{50} = 27.7 μM/OVCAR	
		IC_{50} = 77.2 μM/MCF-7	
89	*In vitro*	IC_{50} = 8.2 μM/HepG-2	[42]
		IC_{50} = 9.3 μM/A-549	
		IC_{50} = 9.2 μM/MCF-7	
		IC_{50} = 8.5 μM/SW-26	
90	*In vitro*	IC_{50} = 3.4 μM/HepG-2	[42]
		IC_{50} = 4.4 μM/A-549	
		IC_{50} = 4.7 μM/MCF-7	
		IC_{50} = 6.6 μM/SW-26	
91	*In vitro*	IC_{50} = 47.0 μM/HepG-2	[42]
		IC_{50} = 49.3 μM/A-549	
		IC_{50} = 51.9 μM/MCF-7	
		IC_{50} = 54.4 μM/SW-26	
92	*In vitro*	IC_{50} = 7.6 μM/HepG-2	[42]
		IC_{50} = 8.0 μM/A-549	
		IC_{50} = 8.8 μM/MCF-7	
		IC_{50} = 9.1 μM/SW-26	
93	*In vitro*	IC_{50} = 9.9 μM/HepG-2	[42]
		IC_{50} = 8.6 μM/A-549	
		IC_{50} = 10.2 μM/MCF-7	
		IC_{50} = 10.1 μM/SW-26	
The methanol extract of *G. velutinum* leaves	*In vitro*	IC_{50} = 431.78 μg/mL/MCF-7	[67]
		IC_{50} = 89.02 μg/mL/PC-3	
The *n*-hexane fraction of *G. velutinum* leaves	*In vitro*	IC_{50} = 523.63 μg/mL/MCF-7	[67]
		IC_{50} = 325.87 μg/mL/PC-3	
The chloroform fraction of *G. velutinum* leaves	*In vitro*	IC_{50} = 222.27 μg/mL/MCF-7	[67]
		IC_{50} = 27.63 μg/mL/PC-3	
The ethyl acetate fraction of *G. velutinum* leaves	*In vitro*	IC_{50} = 226.35 μg/mL/MCF-7	[67]
		IC_{50} = 196.83 μg/mL/PC-3	
The *n*-butanol fraction of *G. velutinum* leaves	*In vitro*	IC_{50} = 123.36 μg/mL/PC-3	[67]
The aqueous fraction of *G. velutinum* leaves	*In vitro*	IC_{50} = 522.41 μg/mL/MCF-7	[67]
		IC_{50} = 36.95 μg/mL/PC-3	

(Continued)

Table 2. Continued

Compounds	Models	Effect	References
The methanol extract of *G. multiloculare* stem barks (20 mg/kg, i.p.)	*In vivo*	24 Days of survival/mice bearing EAC	73
The petroleum ether fraction of *G. multiloculare* stem barks (20 mg/kg, i.p.)	*In vivo*	26 Days of survival/mice bearing EAC	73
The carbontetrachloride fraction of *G. multiloculare* stem barks (20 mg/kg, i.p.)	*In vivo*	21 Days of survival/mice bearing EAC	73
The chloroform fraction of *G. multiloculare* stem barks (20 mg/kg, i.p.)	*In vivo*	27 Days of survival/mice bearing EAC	73
Antioxidative activity			
143	*In vitro*	IC_{50} = 11.1 μg/mL/DPPH radicals	6
146	*In vitro*	IC_{50} = 13.0 μg/mL/DPPH radicals	6
166	*In vitro*	IC_{50} = 2.5 μg/mL/DPPH radicals	6
177	*In vitro*	IC_{50} = 4.2 μg/mL/DPPH radicals	6
238	*In vitro*	IC_{50} = 302.5 μg/mL/DPPH radicals	61
The methanol extract of *G. sphaerogynum* barks	*In vitro*	IC_{50} = 37.4479 μg/mL/DPPH radicals	66
The methanol extract of *G. hypoleucum* leaves	*In vitro*	IC_{50} = 40 μg/mL/DPPH radicals	6
The 95% ethanol extracts of *G. hirsutum* leaves	*In vitro*	181.74 μg AAE/g DW/DPPH radicals	69
The 95% ethanol extracts of *G. sphaerogynum* leaves	*In vitro*	42.19 μg AAE/g DW/DPPH radicals	69
The methanol extract of *G. zeylanicum* leaves	*In vitro*	IC_{50} = 6.56 μg/mL/DPPH radicals	70
The methanol extract of *G. zeylanicum* leaves	*In vitro*	IC_{50} = 3.76 μg/mL/ABTS radicals	70
The 80% ethanol extract of *G. wallichianum* leaves	*In vitro*	2.3 mmole TE/g DW/DPPH radicals 1.9 mmole TE/g DW/ABTS radicals 1.1 mmole TE/g DW/FRAP	74
The methanol extract of *G. multiloculare* barks	*In vitro*	IC_{50} = 16.46 μg/mL/DPPH radicals	75
Antimicrobial activity			
31	*In vitro*	MIC = 128 μM/B. subtilis and MRSA	76
31 + tetracycline	*In vitro*	FICI = 0.5156 and time-kill of 4.0 h/B. subtilis FICI = 0.5313 and time-kill of 6.0 h/MRSA	76
32	*In vitro*	MIC = 64 μM/*P. aeruginosa*	39
33	*In vitro*	MIC = 64 μM/*P. aeruginosa* and *E. coli*	39
34	*In vitro*	MIC = 2048 μM/*P. aeruginosa*	39
45	*In vitro*	MIC = 512 μM/*P. aeruginosa* and *E. coli*	39
49	*In vitro*	MIC = 2048 μM/*E. coli* MIC = 1024 μM/*P. aeruginosa*	39
154	*In vitro*	71% Inhibition/*P. aeruginosa* at 175 μM 49% Inhibition/*S. aureus* at 175 μM	53
156	*In vitro*	56% Inhibition/*P. aeruginosa* at 17.5 μM 70% Inhibition/*S. aureus* at 70 μM	53
158	*In vitro*	52% Inhibition/*P. aeruginosa* at 175 μM	53
177	*In vitro*	MIC = 50 μg/mL and MBC = 100 μg/mL/MRSA	55
238	*In vitro*	IZ = 12 mm/*B. cereus* IZ = 9 mm/*S. aureus* IZ = 10 mm/*E. faecalis* and *P. vulgaris* IZ = 8 mm/*E.coli* EPEC, *E. coli* ATCC, and *K. oxytoca* IZ = 7 mm/*K. michiganensis* IZ = 5 mm/*E.coli* ETEC IZ = 11 mm/*S. typhi*	61
The petroleum ether extract of *G. multiloculare* barks	*In vitro*	IZ = 10 mm/*V. parahemolyticus*, *C. albicans*, *A. niger*, and *S. cerevaceae* IZ = 9 mm/*B. cerus*, *B. megaterium*, *B. subtilis*, *S. lutea*, *Sh. boydii*, and *V. mimicus* IZ = 8 mm/*E. coli*, *P. aeruginosa*, *S. typhi*, and *Sh. dysenteriae*	77
The chloroform extract of *G. multiloculare* barks	*In vitro*	IZ = 12 mm/*B. subtilis* IZ = 11 mm/*E. coli* IZ = 10 mm/*B. cerus*, *B. megaterium*, *S. lutea*, *P. aeruginosa*, *S. typhi*, *Sh. dysenteriae*, *Sh. boydii*, *V.*	77

(Continued)

Table 2. Continued

Compounds	Models	Effect	References
		parahemolyticus, and *S. cerevaceae*	
		IZ = 9 mm/*V. mimicus*, *C. albicans*, and *A. niger*	
The carbon tetrachloride extract of *G. multiloculare* barks	*In vitro*	IZ = 7 mm/*Sh. boydii*, and *V. mimicus*	77
		IZ = 8 mm/*B. cerus*, *B. megaterium*, *S. lutea*, *P. aeruginosa*, *S. typhi*, *Sh. dysenteriae*, *C. albicans*, and *V. parahemolyticus*	
		IZ = 9 mm/*E. coli*, *S. cerevaceae*, and *A. niger*	
G. candolleanum leaf-silver nanoparticles	*In vitro*	IZ = 12.2 mm/*S. enterica*	78
		IZ = 11.8 mm/*P. aeruginosa*	
The ethanol extract of *G. puberum* roots	*In vitro*	MIC = 100 μg/mL/*B. subtitis*	79
		MIC = 200 μg/mL/*P. aeruginosa*	
Antiinflammatory activity			
7	*In vitro*	IC_{50} = 16 μM/NO	1
24	*In vitro*	IC_{50} = 60.5 μM/NOS	35
55	*In vitro*	IC_{50} = 39.5 μM/NOS	35
		IC_{50} = 80.9 μM/NOX	
58	*In vitro*	IC_{50} = 60.6 μM/NOS	35
		IC_{50} = 52.2 μM/NOX	
99	*In vitro*	IC_{50} = 78.7 μM/NOS	35
121	*In vitro*	IC_{50} = 78.9 μM/NOS	35
142	*In vitro*	IC_{50} = 80.1 μM/NOS	35
147	*In vitro*	IC_{50} = 65.7 μM/NOS	35
161	*In vitro*	IC_{50} = 98.4 μM/NOS	35
The ethanol extract of G. thomsonii barks (250 and 500 mg/kg, p.o.)	*In vivo*	To inhibit carrageenan mediated paw edema and xylene mediated ear edema in mice	18
The n-hexane, dichloromethane, and n-butnanol extracts of G. ellipticum leaves (200 mg/kg, p.o.)	*In vivo*	To ameliorate DSS-stimulated colitis in mice via the NF-κB signaling inhibition	80
The methanol extract and its petroleum ether, carbon tetrachloride, and chloroform fractions of *G. multiloculare* stem bark (100 mg/kg, i.p.)	*In vivo*	To inhibit carrageenan induced paw edema in mice	73
Antidiabetic activity			
The 95% ethanol extract of *G. hirsutum* leaves	*In vitro*	IC_{50} = 1.01 mg/mL/α-amylase	69
		IC_{50} = 0.59 mg/mL/α-glucosidase	
The 95% ethanol extract of *G. sphaerogynum* leaves	*In vitro*	IC_{50} = 2.21 mg/mL/α-amylase	69
		IC_{50} = 2.84 mg/mL/α-glucosidase	
The ethanol extract of *G. arborescens* leaves and *C. ramiflora* leaves	*In vitro*	IC_{50} = 374.47 ppm/α-glucosidase enzyme	81
The ethanol extract of *G. velutinum* leaves (200 and 400 mg/kg, p.o.)	*In vivo*	To inhibit streptozotocin-nicotinamide stimulated type 2 diabetic mice	82
The aqueous extract of *G. zylanicum* roots (200 and 400 mg/kg, p.o.)	*In vivo*	To reduce blood glucose levels in mice	19
The aqueous extract of *G. velutinum* leaves (400 mg/kg, p.o.)	*In vivo*	To reduce blood glucose levels in mice	20
Antiurolithiatic activity			
The methanol extract of *G. velutinium* leaves (500 mg/kg, p.o.)	*In vivo*	To suppress the CAOX crystal formation in calculogenic mice	83
Antidiarrheal activity			
The ethanol extract of *G. thomsonii* barks (500 mg/kg, p.o.)	*In vivo*	To inhibit castor oil induced diarrhea in mice by 54.47%, and reduce the intestinal fluid accumulation by 51.6%	84
Analgesic activity			
The methanol extract of *G. multiloculare* stem barks (20 mg/kg, i.p.)	*In vivo*	70% Inhibition/acetic acid induced writhing in mice	73
The petroleum ether fraction of *G. multiloculare* stem barks (20 mg/kg, i.p.)	*In vivo*	66.36% Inhibition/acetic acid induced writhing in mice	73
The carbontetrachloride fraction of *G. multiloculare* stem barks (20 mg/kg, i.p.)	*In vivo*	83.25% Inhibition/acetic acid induced writhing in mice	73
The chloroform fraction of *G. multiloculare* stem barks (20 mg/kg, i.p.)	*In vivo*	84.09% Inhibition/acetic acid induced writhing in mice	73

(Continued)

Table 2. Continued

Compounds	Models	Effect	References
The ethanol extract of G. thomsonii barks (250 and 500 mg/kg, p.o.)	*In vivo*	To suppress formalin mediated paw licking and acetic acid mediated writhing in mice	18
Sedative activity			
The methanol extract of *G. multiloculare* leaves (200 mg/kg, p.o.)	*In vivo*	To decrease the locomotor activity of mice in hole cross, opening field, and prolonging the sleeping time	5
Neuroprotective activity			
The ethanol extract of *G. zeylanicum* leaves (10 μg/mL)	*In vitro*	To protect against glutamate/H_2O_2-induced toxicity in HT-22 and Neuro-2a neuronal cells	85
The ethanol extract of *G. zeylanicum* leaves (5 μg/mL)	*In vitro*	To protect against Aβ-induced toxicity in *C. elegans* and enhance neuritogenesis in neuro-2a cells	85
The aqueous extract of *G. littorale* leaves at the concentration of 100–200 μg/mL	*In vitro*	To protect against MMP^+ induced toxcity in *C. elegans* by DAF-16 transcription activation	86
Liver protective activity			
The ethanol extract of *G. wallichianum* leaves (300 and 600 mg/kg, p.o.)	*In vivo*	To suppress ethanol induced liver damage in mice via antioxdative activity	87
Skin protective activity			
The methanol extract *G. zeylanicum* leaves	*In vitro*	IC_{50} = 47.94 μg/mL/elastase IC_{50} = 76.00 μg/mL/tyrosine	70
Anti 5α-reductase acitivity			
The 50% ethanol extract of *G. eriocarpum* roots (200 μg/mL)	*In vitro*	25.5% Inhibition/5α-reductase enzyme	88
Hemolysis			
The ethanol leaf extract of *G. zeylanicum* (75 μg/mL)	*In vitro*	60.52% Inhibition/red blood cell destruction	89
Mosquito larvicidal activity			
The ethyl acetate extract of *G. laneolarium* leaves	*In vitro*	-80% Morality rate, LC_{50} = 55.73 ppm and LC_{90} = 127 ppm/*Cx. vishnui* third larvae for 24 h -85.33% Morality rate, LC_{50} = 52.10 ppm and LC_{90} = 89.24 ppm/*Cx. vishnui* third larvae for 48 h -100% Morality rate, LC_{50} = 48.68 ppm and LC_{90} = 74.64 ppm/*Cx. vishnui* third larvae for 24h	90
Toxicology			
The methanol extract of *G. multiloculare* leaves	*In vitro*	LC_{50} = 37.19 μg/mL/*A. salina*	5
The *n*-hexane extract of *G. velutinum* leaves	*In vitro*	LC_{50} = 598.54 μg/mL/*A. salina*	91
The ethyl acetate extract of *G. velutinum* leaves	*In vitro*	LC_{50} = 651.92 μg/mL/*A. salina*	91
The methanol extract of *G. velutinum* leaves	*In vitro*	LC_{50} = 428.47 μg/mL/*A. salina*	91
The petroleum ether extract of *G. multiloculare* barks	*In vitro*	LC_{50} = 3.11 μg/mL/*A. salina*	77
The carbon tetrachloride extract of *G. multiloculare* barks	*In vitro*	LC_{50} = 4.96 μg/mL/*A. salina*	77
The chloroform extract of *G. multiloculare* barks	*In vitro*	LC_{50} = 7.56 μg/mL/*A. salina*	77
The methanol extract of *G. multiloculare* barks	*In vitro*	LC_{50} = 9.23 μg/mL/*A. salina*	77
The aqueous extract of *G. multiloculare* barks	*In vitro*	LC_{50} = 16.32 μg/mL/*A. salina*	77

other neurodegenerative diseases due to its intriguing neuritogenesis and neuroprotective properties. Herein, it protected against glutamate/H_2O_2-induced toxicity in HT-22 and neuro-2a neuronal cells by suppressing the intracellular ROS generation and enhancing the expression of endogenous antioxidative enzymes SODs, GPx, and GSTs at the concentration of 10 μg/mL.[85] This extract also triggered SIRT1/Nrf2 protein expression and mRNA transcription of antioxidative genes NQO1, GCLM, and EAAT3. In addition, at the concentration of 5 μg/mL, it showed protective activity against Aβ (amyloid-β)-induced toxicity in *Caenorhabditis elegans* and enhanced neuritogenesis in neuro-2a cells.[85]

The neuroprotective effect of *G. zelanicum* leaf extract was explained by extending lifespan and oxidative stress suppression in *C. elegans* via DAF-16/FoxO and SKN-1/Nrf-2 signaling pathways.[2,3] The aqueous extract of *G. littorale* leaves at the concentration of 100–200 μg/mL ameliorated H_2O_2 induced oxidative stress by ROS accumulation, and 1-methyl-4-phenylpyridinium ion (MMP^+) induced neurodegeneration in *C. elegans* by DAF-16 transcription activation.[86]

Liver, and Skin Protective Activities

Chronic ethanol consumption can lead to a drastic growth of liver ailments.[87] It was noted that the ethanol extract of *G. wallichianum* leaves at two doses of 300 and 600 mg/kg, p.o., suppressed ethanol-stimulated liver damage in mice for 28 days via antioxidative activity.[87] Herein, the mechanism of action involved decreases in alanine aminotransferase (ALT), hepatic malondialdehyde (MDA) levels, an increase in catalase (CAT) activity, and an improvement in histopathological alterations.[87] In a clinical setting, the dogs treated with *G. ferdinandi* roots for 30 days revealed a health status with serum biochemical and coagulation profile within reference intervals.[94]

The methanol extract of *G. zeylanicum* leaves possessed the IC_{50} values of 47.94 and 76.00 μg/mL in elastase and tyrosine inhibitory assays, respectively.[70] Microemulsions containing *G. wallichianum* extract and surfactants (labrasol/HCO-40 (1:1) with transcutol (1:1, 2:1, 3:1), and tween 80/span 80 (3:2) with transcutol or propylene glycol/ethanol (1:1)) have potential for transdermal and topical skin delivery of gallic acid.[95]

Other Activities

As we know, the 5α-reductase suppressor plays a great role in the management of male pattern hair loss. It turns out that the 50% ethanol extract of *G. eriocarpum* roots at 200 μg/mL inhibited 25.5% growth of the 5α-reductase enzyme.[88] The ethanol leaf extract of *G. zeylanicum* at the concentration of 75 μg/mL induced 60.52% inhibition of red blood cell destruction, as compared with that of the standard diclofenac (75.78%).[89] At a concentration of 50 ppm, the ethyl acetate extract of *G. laneolarium* leaves showed mosquito larvicidal activity against *Culex vishnui* third larval instars with mortality rates of 80, 85.33, and 100% for 24, 48, and 72 h treatments, respectively.[90]

Toxicology

The methanol extract of *G. multiloculare* leaves and the standard vincristine sulfate showed the corresponding LC_{50} values of 37.19 and 10.50 μg/mL in a brine shrimp lethal assay against *Artemia salina*.[5] In the same model, the *n*-hexane, ethyl acetate, and methanol extracts of *G. velutinum* leaves exerted the LC_{50} values of 598.54, 651.92, and 428.47 μg/mL, respectively.[91] The extracts of *G. multiloculare* barks induced resistance to *A. salina* with the LC_{50} values of 3.11–16.32 μg/mL.[77]

Conclusions and Perspectives

The current study first reviews full information about the phytochemistry and pharmacology aspects of *Glochidion* species. About 25 species have been the main objects of phytochemical research. Through chromatographic separation and NMR elucidation, more than 240 sary metabolites have been isolated and identified. They included terpenoids, sterols, saponins, lignans, flavonoids, *mono*-phenols, megastigmanes, butenolides, glycosides, alkaloids, cyanogens, tocopherols, fatty acids, and others. Three triterpenoids glochidonol, glochidiol, and glochidone can be seen as characteristic compounds present in this genus since they were found in frequency. The GC-MS studies reported the presence of aliphatic and terpenic compounds in *Glochidion* essential oils, whereas total phenolic and flavonoid contents were found to be different in each *Glochidion* species. Plants from this genus were documented to exhibit a wide range of *in vitro* pharmacological values, consisting of cytotoxic, antioxidative, antimicrobial, antiinflammatory, antidiabetic, antiurolithiatic, antidiarrheal, analgesic, and sedative activities, as well as living organ protection.

Although there have been plenty of phytochemical investigations, the isolated compounds were present in trace amounts. It is necessary to propose an advanced method to obtain huge amounts. Most pharmacological results were obtained at *in vivo* levels, and biomedical examinations of various compounds, especially in terms of new compounds are still unknown. Besides this, pharmacokinetics, clinical applications, nano-encapsulations, and synergistic combinations are expected.

List of abbreviations

ABTS	2,2'-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)
ALT	Alanine aminotransferase
ASS	Atomic absorption spectrometry
Aβ	β-Amyloid
BHT	Butylated hydroxyl toluene
CAT	Catalase
CE	Catechin equivalent
COX-2	Cyclooxygenase-2
DPPH	2,2-diphenyl-1-picrylhydrazyl
DSS	Dextran sulfate sodium
DW	Dried weight
EBV-EA	Epstein-Barr virus early antigen
EAC	Ehrlich's ascites carcinoma
FICI	Fractional inhibitory concentration index
FW	Fresh weight
FRAP	Ferric reducing antioxidant power
GAE	Gallic acid equivalent
GC-MS	Gas chromatography mass spectrometry
IC_{50}	Haft maximal inhibitory concentration
IZ	Inhibition zone
iNOS	Inducible nitric oxide
i.p.	Intraperitoneal injection
LC-MS	Liquid chromatography mass spectrometry
LPS	Lipopolysaccharide
MDA	Malondialdehyde
MIC	Minimum inhibitory concentration
MBC	Minimum bactericidal concentration
MMP^+	1-Methyl-4-phenylpyridinium ion
MRSA	Methicillin resistant Staphylococcus aureus
NF-kB	Nuclear factor-kappa B
NO	Nitric oxide
NOX	NADPH oxidase
p.o.	Oral administration
QE	Quercetin equivalent
ROS	Reactive oxygen species
TPC	Total phenolic content
TFC	Total flavonoid content
TE	Trolox equivalent
TPA	12-O-Tetradecanoylphorbol 13-acetate.

Acknowledgments

The authors would like to express their sincere gratitude to supporters for their revisions.

Authors Contributions

Conceptualization: N. N. L.; Formal analysis: P. T. T. N.; Validation: P. T. B. D.; Data collection: V. Q. M., and T. V. P.; writing-original draft preparations and supervision: N. T. S. All authors have read and agreed to the published version of the manuscript

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Ty Viet Pham https://orcid.org/0000-0002-6883-0823
Ninh The Son https://orcid.org/0000-0002-2413-7496

Statement of Institutional Review Board

Not applicable.

Statement of Informed Consent

Not applicable.

References

1. Gao R, Xu X, Sun H, et al. Norbisabolane-type sesquiterpenoid derivatives, benzofuran lignans and a phenolic glycoside from the roots of *Glochidion wilsonii* hutch. *Phytochemistry*. 2022;204:113447.
2. Duangjan C, Rangsinth P, Gu X, Zhang S, Wink M, Tencomnao T. Data on the effects of *Glochidion zeylanicum* leaf extracts in *Caenorhabditis elegans*. *Data Brief*. 2019;26:104461.
3. Duangjan C, Rangsinth P, Gu X, Zhang S, Wink M, Tencomnao T. *Glochidion zeylanicum* leaf extracts exhibit lifespan extending and oxidative stress resistance properties in *Caenorhabditis elegans* via DAF-16/FoxO and SKN-1/Nrf-2 signaling pathways. *Phytomedicine*. 2019;64:153061.
4. Hammer K, Pignone D, Cifarelli S, Perrino P. Barilla (*Salsola soda*, chenopodiaceae). *Economic Bot*. 1990;44(3):410-412.
5. Ali MS, Al Mamun MA, Abu Sayeed M, Rahman MS, Rashid MA. Sedative activity of methanolic extract of *Glochidion multiloculare* (Rottler ex Willd) Voigt leaves. *Pak J Biol Sci*. 2014;17(4):555-559.
6. Anantachoke N, Kitphati W, Mangmool S, Bunyapraphatsara N. Polyphenolic compounds and antioxidant activities of the leaves of *Glochidion hypoleucum*. *Nat Prod Commun*. 2015;10(3):479-482.
7. Yang J, Yang XD, Wu HY, Zhao QL, Zhao JF, Li L. Chemical study on *Glochidion hirsutum* (II). *Nat Prod Res Dev*. 2007;19(6):986-988.
8. Xiao HT, Hao XY, Yang XW, et al. Bisabolane-type sesquiterpenoids from the rhizomes of *Glochidion coccineum*. *Helv Chim Acta*. 2007;90(1):164-170.
9. Liu XQ, Huang HL, Yao MJ, et al. Oleanane-type triterpenoids from *Glochidion assamicum*. *Helv Chim Acta*. 2011;94(12):2264-2271.
10. Zhang X, Chen J, Gao K. Chemical constituents from *Glochidion wrightii* Benth. *Biochem Syst Ecol*. 2012;45:7-11.
11. Thu VK, Kieu Anh LT, Quang DN, et al. Triterpenes from the leaves of *Glochidion obliquum*. *Vietnam J Chem*. 2015;53(2E):103-106.
12. Thu VK, Van Thang N, Nhiem NX, et al. Oleanane-type saponins from *Glochidion glomerulatum* and their cytotoxic activities. *Phytochemistry*. 2015;116:213-220.
13. Thu VK, Thang NV, Nhiem NX, et al. Oleanane-type triterpene saponins from *Glochidion glomerulatum*. *Nat Prod Commun*. 2015;10(6):875-876.
14. Thu VK, Thang NV, Nhiem NX, et al. Two new compounds from the leaves of *Glochidion obliquum*. *Nat Prod Commun*. 2016;11(4):443-444.
15. Thu VK, Thang NV, Tuan Anh HL, et al. Flavones and lignanes from *Glochidion obliquum* Decne. *Vietnam J Chem*. 2016;54(2):184-187.
16. Okamoto T, Kawakita A, Kato M. Interspecific variation of floral scent composition in glochidion and its association with host-specific pollinating seed parasite (Epicephala). *J Chem Ecol*. 2007;33(5):1065-1068.
17. Huang D, Shi F, Chai M, Li R, Li H. Interspecific and intersexual differences in the chemical composition of floral scent in *Glochidion* species (Phyllanthaceae) in south China. *J Chem*. 2015;2015:865694.
18. Rahman MH, Oliullah ABM, Rahman MM, Alam MJ, Shahriar M, Jahan FI. Anti-inflammatory and analgesic activities of ethanolic extract of *Glochidion thomsonii* (bark). *Pharmacologyonline*. 2018;3:317-323.
19. Sharma JVC, Satyavahti D, Venkateswararao J, Sharmla S, Abedullakhan K, Rao AS. Hypoglycemic activity of aqueous root extract of *Glochidion zylanicum*. *J Chem Pharm Sci*. 2010;3:35-37.
20. Rao NVR, Nadendla R, Arunkumar M, et al. Anti-diabetic activity of *Glochidion velutinum* L. extract in alloxan-induced type-II diabetic rats. *Int J Phytopharm*. 2013;4(5):311-314.
21. Liu M, Xiao HT, He HP, Hao XY. A novel lignanoid and norbisabolane sesquiterpenoids from *Glochidion puberum*. *Chem Nat Compd*. 2008;44(5):588-590.
22. Ganguly AK, Govindachari TR, Mohamed PA, Rahimtulla AD, Viswanathan N. Chemical constituents of *Glochidion hohenackeri*. *Tetrahedron*. 1966;22(4):1513-1519.
23. Hui WH, Fung ML. An examination of the Euphorbiaceae of Hong Kong. VI. Isolation and structure of glochidonol, a new triterpene ketol from *Glochidion wrightii* Benth. *J Chem Soc Perkin*. 1969;1(13):1710-1712.
24. Hui WH, Lee WK, Ng KK, Chan CK. An examination of the euphorbiaeceae of Hong Kong. Part VII. Occurrence of triterpeonoids and steroids in three *Glochidion* species. *Phytochemistry*. 1970;9(5):1099-1102.
25. Hui WH, Lee WK. An examination of the Euphorbiaceae of Hong Kong. Part VIII. Lup-20(29)-ene-3α,23-diol, a new triterpene from *Glochidion macrophyllum* benth. *J Chem Soc C*. 1971:1004-1006.
26. Ahmad SA, Zaman A. Chemical constituents of *Glochidion venulatum*, *Maesa indica* and *Rhamnus triquetra*. *Phytochemistry*. 1973;12(7):1826.
27. Hui WH, Li MM. Lupene triterpenoids from *Glochidion eriocarpum*. *Phytochemistry*. 1976;15:561-562.
28. Hui WH, Li MM. Triterpenoids from *Glochidion macrophyllum* and *G. puberum*. *Phytochemistry*. 1978;17(1):156-157.

29. Carpenter RC, Sotheeswaran S, Uvais M, Sultanbawa S, Balasubramaniam S. Triterpenes of five *Euphorbiaceae* species of Sri Lanka. *Phytochemistry*. 1980;19(6):1171-1174.
30. Srivastava R, Kulshreshtha DK. Triterpenoids from *Glochidion heyneanum*. *Phytochemistry*. 1988;27(11):3575-3578.
31. Tanaka R, Kinouchi Y, Wada S, Tokuda H. Potential anti-tumor promoting activity of lupane-type triterpenoids from the stem bark of *Glochidion zeylanicum* and *Phyllanthus flexuosus*. *Planta Med*. 2004;70(12):1234-1236.
32. Puapairoj P, Naengchomnong W, Kijjoa A, et al. Cytotoxic activity of lupane-type triterpenes from *Glochidion sphaerogynum* and *Glochidion eriocarpum* two of which induce apoptosis. *Planta Med*. 2005;71(3):208-213.
33. Kiem PV, Thu VK, Yen PH, et al. New triterpenoid saponins from *Glochidion eriocarpum* and their cytotoxic activity. *Chem Pharm Bull*. 2009;57(1):102-105.
34. Thu VK, Kiem PV, Yen PH, et al. Triterpenoids from aerial parts of *Glochidion eriocarpum*. *Nat Prod Commun*. 2010;5(3):361-364.
35. Thang TD, Kuo PC, Yu CS, et al. Chemical constituents of the leaves of *Glochidion obliquum* and their bioactivity. *Arch Pharm Res*. 2011;34:383-389.
36. Hasan AA, Azam ATMZ, Hasan CM, Haque MR. Triterpenoids and steroids isolated from aerial parts of *Glochidion multiloculare*. *Pak J Sci Ind Res A: Phys Sci*. 2012;55(3):163-168.
37. Tian JM, Fu XY, Zhang Q, He HP, Gao JM, Hao XJ. Chemical constituents from *Glochidion assamicum*. *Biochem Syst Ecol*. 2013;48:288-292.
38. Tian Y, Fan R, Yin Z, et al. Glochodpurnoid B from *Glochidion puberum* induces endoplasmic reticulum stress-mediated apoptosis in colorectal cancer cells. *Molecules*. 2023;28(2):511.
39. Trongdee R, Kongcharoensuntorn R. Antibacterial and antibiofilm activities of lupanes from *Glochidion daltonii* against some opportunistic bacteria. *J Food Sci Agri Technol*. 2022;6:104-108.
40. Zhang Z, Liu GM, Ren YL, He HP, Hao XJ. Chemical constituents from *Glochidion puberum*. *Nat Prod Res Dev*. 2008;20(3):447-449.
41. Srivastava R, Kulshreshtha DK. Glochidioside a terpenene glycoside from *Glochidion heyneanum*. *Phytochemistry*. 1986;25(11):2672-2674.
42. Thang NV, Thu VK, Nhiem NX, et al. Oleanane-type saponins from *Glochidion hirsutum* and their cytotoxic activities. *Chem Biodivers*. 2017;14(5):e1600445.
43. Zhang Z, Gao ZL, Fang X, et al. Two new triterpenoid saponins from Glochidion puberum. *J Asian Nat Prod Res*. 2008;10(11):1029-1034.
44. Zhang Z, Fang X, Wang YH, et al. Puberosides C–E, triterpenoid saponins from *Glochidion puberum*. *J Asian Nat Prod Res*. 2011;13(9):838-844.
45. Otsuka H, Hirata E, Shinzato T, Takeda Y. Isolation of lignan glucosides and neolignan sulfate from the leaves of *Glochidion zeylanicum* (Gaertn) A. Juss. *Chem Pharm Bull*. 2000;48(7):1084-1086.
46. Cai WH, Matsunami K, Otsuka H, Shinzato T, Takeda Y. Lignan and neolignan glucosides, and tachioside 2'-*O*-4''-*O*-methylgallate from the leaves of *Glochidion rubrum*. *J Nat Med*. 2009;63:408-414.
47. Xiao HT, He HP, Peng J, et al. Two new norbisabolane sesquiterpenoid glycosides from *Glochidion coccineum*. *J Asian Nat Prod Res*. 2008;10(1):1-5.
48. Wang Y, Zhu H, Wang D, et al. A new phloroglucinol glucoside from the whole plants of *Glochidion eriocarpum*. *Bull Korean Chem. Soc*. 2014;35(2):631-634.
49. Takeda Y, Mima C, Masuda T, Hirata E, Takushi A, Otsuka H. Glochidioboside, a glucoside of (7*S*,8*R*)-dihydrodehydrodiconiferyl alcohol from leaves of *Glochidion obovatum*. *Phytochemistry*. 1998;49(7):2137-2139.
50. Otsuka H, Hirata I, Shinzato T, Takeda Y. Glochiflavanosides A-D: flavanol glucosides from the leaves of *Glochidion zeylanicum* (Gaertn) A. Juss. *Chem Pharm Bull*. 2001;49(7):921-923.
51. Yamashita-Higuchi Y, Sugimoto S, Matsunami K, Inagaki M, Otsuka H, Takeda Y. Nitrile-containing phenolic glucosides from the leaves of *Glochidion acuminatum*. *Chem Pharm Bull*. 2015;63(1):49-53.
52. Chen LG, Yang LL, Yen KY, Hatano T, Yoshida T, Okuda T. Tannins of *Euphorbiaceous* plants. XIII. New hydrolyzable tannins having phloroglucinol residue from *Glochidion rubrum* BLUME. *Chem Pharm Bull*. 1995;43(12):2088-2090.
53. Yin S, Sykes ML, Davis RA, et al. New galloylated flavanonols from the Australian plant *Glochidion sumatranum*. *Planta Med*. 2010;76(16):1877-1881.
54. Otsuka H, Takeda Y, Hirata E, Shinzato T, Bando M. Glochidiolide, isoglochidiolide, acuminaminoside, and glochidacuminosides A-D from the leaves of *Glochidion acuminatum* MUELL. *Chem Pharm Bull*. 2004;52(5):591-596.
55. Ahmed MD, Taher M, Maimusa AH, Rezali MF, Mahmud MI. Antimicrobial activity of methyl gallate isolated from the leaves of *Glochidion superbum* against hospital isolates of methicillin resistant *Staphylococcus aureus*. *Nat Prod Sci*. 2017;23(1):5-8.
56. Otsuka H, Kijima H, Hirata E, et al. Glochidionionosides A-D: megastigmane glucosides from leaves of *Glochidion zeylanicum* (Gaertn. *A. Juss. Chem Pharm Bull*. 2003;51(3):286-290.
57. Otsuka H, Hirata E, Shinzato T, Takeda Y. Stereochemistry of megastigmane glucosides from *Glochidion zeylanicum* and *Alangium premnifolium*. *Phytochemistry*. 2003;62(5):763-768.
58. Otsuka H, Kotani K, Bando M, Kido M, Takeda Y. A novel dimeric butenolide, glochidiolide, from the leaves of *Glochidion acuminatum* MUELL. *Chem Pharm Bull*. 1998;46(7):1180-1181.
59. Otsuka H, Hirata E, Takushi A, et al. Glochidionolactones A-F: butenolide glucosides from leaves of *Glochidion zeylanicum* (GAERTN) A. JUSS. *Chem Pharm Bull*. 2000;48(4):547-551.
60. Johns SR, Lamberton JA. New histamine alkaloids from a *Glochidion* Species. *Chem Commun*. 1966;10:312-313.
61. Das AK, Khan J, Ahmad M, Rahman A, Hossain ME. A new cinnamic ester derivative from *Glochidion velutinum* leaves and evaluation of its antioxidant and antibacterial activity. *Indian J. Chem*. 2022;61(9):989-993.
62. Davis RA, Andjic V, Kotiw M, Shivas RG. Phomoxins B and C: polyketides from an endophytic fungus of the genus *Eupenicillium*. *Phytochemistry*. 2005;66(23):2771-2775.
63. Ha NM, Son NT. The genus *Cryptocarya*: a review on phytochemistry and pharmacological activities. *Chem Biodivers*. 2023;20(3): e202201102.
64. Hop NQ, Son NT. Botanical description, traditional uses, phytochemistry, and pharmacology of the genus Artabotrys: a review. *Chem Biodivers*. 2022;19(11):e202200725.

65. Son NT. Genus *Acronychia*: an extensive review on phytochemistry and pharmacological activities. *Mini-rev org chem*. 2023;20(8):818-841.
66. Brahma P, Baruah S. Investigation of phytochemical constituents, GC-MS, DPPH free radical scavenging assay, and mineral contents of *Glochidion sphaerogynum* (mull. Arg.) Kurz bark extract. *Plant Sci Today*. 2023;10(2):98-105.
67. Shah SL, Bashir K, Rasheed HM, et al. LC-MS/MS-based metabolomic profiling of constituents from *Glochidion velutinum* and its activity against cancer cell lines. *Molecules*. 2022;27(24):9012.
68. Vinayaka KS, Hallur RLS, Kekuda P. Preliminary phytochemical analysis and *in vitro* antioxidant activity of *Glochidion ellipticum* Wight (Phyllanthaceae). *Biomedicine*. 2022;42(1):148-153.
69. Dedvisitsakul P, Watla-iad K. Antioxidant activity and antidiabetic activities of northern Thai indigenous edible plant extracts and their phytochemical constituents. *Heliyon*. 2022;8:e10740.
70. Chaikhong K, Chumpolphant S, Rangsinth P, et al. Antioxidant and anti-skin aging potential of selected Thai plants: *in vitro* evaluation and *in silico* target prediction. *Plants*. 2022;12(1):65.
71. Kongkachuichai R, Charoensiri R, Yakoh K, Kringkasemsee A, Insung P. Nutrients value and antioxidant content of indigenous vegetables from southern Thailand. *Food Chem*. 2015;173:838-846.
72. Nhiem NX, Thu VK, Van Kiem P, et al. Cytotoxic oleane-type triterpene saponins from *Glochidion eriocarpum*. *Arch Pharm Res*. 2012;35:19-26.
73. Kabir S, Zahan R, Chowdhury AMS, Haque MR, Rashid MA. Antitumor, analgesic and anti-inflammatory activities of *Glochidion multiloculare* (Rottler ex Willd) Voigt. *Bangladesh Pharm. J*. 2015;18(2):142-148.
74. Wongnen C, Ruzzama N, Chaijan M, Cheong LZ, Panpipat W. *Glochidion wallichianum* leaf extract as a natural antioxidant in sausage model system. *Foods*. 2022;11(11):1547.
75. Azam ATMZ, Hasan AA, Uddin MD, Masud MM, Hasan CM. Antimicrobial, antioxidant and cytotoxic activities of *Glochidion multiloculare* (Roxb. ex Willd.) Müll. Arg. (Euphorbiaceae). *Dhaka Univ J Pharm Sci*. 2013;11:117-120.
76. Kongcharoensuntorn W, Somnuk WW. Antibacterial activity of glochidiol from *Glochidion eriocarpum* enhanced tetracycline against opportunistic bacteria. *Burapha Sci J*. 2021;26(3):1516-1531.
77. Kabir S, Chowdhury AMS, Rashid MA, Hasan CM. Antimicrobial and cytotoxic activities of the extracts of *Glochidion multiloculare*. *J Sci Foundation*. 2012;10(1):1-11.
78. Balachandar R, Navaneethan R, Biruntha M, Kumar KKA, Govarthanan M, Karmegam N. Antibacterial activity of silver nanoparticles phytosynthesized from *Glochidion candolleanum* leaves. *Mater Lett*. 2022;311:131572.
79. Liu Y, Nielsen M, Staerk D, Jäger AK. High-resolution bacterial growth inhibition profiling combined with HPLC–HRMS–SPE–NMR for identification of antibacterial constituents in Chinese plants used to treat snakebites. *J Ethnopharmacol*. 2014;155(2):1276-1283.
80. Hossen I, Hua W, Mehmood A, et al. *Glochidion ellipticum* Wight extracts ameliorate dextran sulfate sodium-induced colitis in mice by modulating nuclear factor kappa-light-chainenhancer of activated B cells signalling pathway. *J Pharm Pharmacol*. 2021;73(3):410-423.
81. Haryoto . Arnida AV, Indrayudha P, Muflihah CH, Yen KH. Inhibitory activity of enzyme α-glucosidase ethanol extract combination of mareme plant (*Glochidion arborescens* (Müll. Arg.) Boerl.) and leaves of the Sala plant (*Cynometra ramiflora* Linn). *Angiotherapy*. 2023;7:1-7.
82. Are PC, Adidala RRR, Puchchakayala G. Hypoglycemic and antidiabetic activity of *Glochidion velutinum* on streptozotocin-nicotinamide induced type 2 diabetic rats. *Eur J Biol Sci*. 2011;3(4):126-130.
83. Vijaya T, Rao NVR, Babu AN, et al. Antiurolithiatic activity of methanolic extract of dried leaves of *Glochidion velutinium* using ethylene glycol induced rats. *Int J Biol Pharm Res*. 2013;4(12):878-884.
84. Jahan N, Ferdousi J, Alam MJ, Rahman T, Rahman M, Shahriar M. Antidiarrheal activity of ethanolic extract of *Melochia corchorifolia* L. and *Glochidion thomsonii* in experimental animal models. *Bangladesh Pharm J*. 2019;22(2):192-199.
85. Duangjan C, Rangsinth P, Zhang S, Gu X, Wink M, Tencomnao T. Neuroprotective effects of *Glochidion zeylanicum* leaf extract against H_2O_2/glutamate-induced toxicity in cultured neuronal cells and Aβ-induced toxicity in *Caenorhabditis elegans*. *Biology (Basel)*. 2021;10(8):800.
86. Bagoudou AF, Zheng Y, Nakabayashi M, et al. *Glochidion littorale* leaf extract exhibits neuroprotective effects in *Caenorhabditis elegans* via DAF-16 activation. *Molecules*. 2021;26(13):3958.
87. Samuhasaneeto S, Punsawad C, Chaniad P. Protective effects of *Glochidion wallichianum* Mull. Arg. on ethanol-induced liver injury in rats. *Trends Sci*. 2022;19(12):4609.
88. Kamei H, Noguchi K, Matsuda H, Murata K. Screening of Euphorbiaceae plant extracts for anti-5α-reductase. *Biol Pharm Bull*. 2018;41(8):1307-1310.
89. Unde EV, Fand SB, Darade AS, Gosavi GR, Murgunde AS. *In-vitro* anti-inflammatory activity of *Glochidion zeylanicum* A. Juss. leaves extract and it's characterization. *Int J Pharm Sci*. 2024;2(1):831-840.
90. Singh A, Bhattacharya K, Chandra G. Larvicidal potentiality of the leaf extracts of *Glochidion lanceolarium* (Phyllanthaceae) against the Japanese encephalitis vector *Culex vishnui* (Culicidae). *Orient Insects*. 2019;53(11):267-278.
91. Hasan MR, Islam T, Shameem MIH, Awoal MA, Islam MS, Rana MS. Evaluation of cytotoxic potentiality of different extracts of *Glochidion velutinum* wight's leaves through brine shrimp lethality bioassay. *World J. Pharm. Res*. 2016;5(1):172-179.
92. Huan DQ, Hop NQ, Son NT. Oxymatrine: a current overview of its health benefits. *Fitoterapia*. 2023;168:105565.
93. Huong DTL, Son NT. Pristimerin: natural occurrence, biosynthesis, pharmacology, and pharmacokinetics. *Rev Bras Farmacogn*. 2024;34:467-480.
94. Griebsch C, Whitney J, Angles J, Bennett P. Acute liver failure in two dogs following ingestion of cheese tree (*Glochidion ferdinandi*) roots. *J Vet Emerg Crit Care*. 2019;29(2):190-200.
95. Yoon AS, Sakdiset P. Development of microemulsions containing *Glochidion wallichianum* leaf extract and potential for transdermal and topical skin delivery of gallic acid. *Sci Pharm*. 2020;88(4):53.